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THIS FIELD OPERATIONS PROCEDURES PLAN (FOP) DETAILS PROCEDURES THAT WILL BE FOLLOWED IN IMPLEMENTING FIELD ACTIVITIES CONDUCTED FOR THE OFF-POST IRA. PROCEDURES DISCUSSED INCLUDE:

1. BOREHOLE DRILLING
2. WELL INSTALLATION AND DEVELOPMENT
3. HYDRAULIC TESTING
4. GEOPHYSICAL METHODS
5. MEASUREMENT/SAMPLING OF GROUND WATER, SURFACE WATER, SOIL, SEDIMENT, AND BIOTA
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TECHNICAL SUPPORT FOR ROCKY MOUNTAIN ARSENAL

Offpost Interim Response Action and
Remedial Investigation/Feasibility Study
Draft Final Field Operations Procedures Plan

August 1989
Contract Number DAAA15-88-D-0021/0001
RIFS1

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PREPARED BY

HARDING LAWSON ASSOCIATES

PREPARED FOR

PROGRAM MANAGER FOR
ROCKY MOUNTAIN ARSENAL

THIS DOCUMENT IS INTENDED TO COMPLY WITH THE NATIONAL ENVIRONMENTAL POLICY ACT OF 1969.

THE INFORMATION AND CONCLUSIONS PRESENTED IN THIS REPORT REPRESENT THE OFFICIAL POSITION OF THE DEPARTMENT OF THE ARMY UNLESS EXPRESSLY MODIFIED BY A SUBSEQUENT DOCUMENT. THIS REPORT CONSTITUTES THE RELEVANT PORTION OF THE ADMINISTRATION RECORD FOR THIS CERCLA OPERABLE UNIT.

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1.0 INTRODUCTION

This Field Operations Procedures Plan (FOP) has been prepared by Harding Lawson Associates (HLA) to detail procedures that will be followed in implementing field activities conducted for the Offpost Interim Response Action and Remedial Investigation/Feasibility Study at the Rocky Mountain Arsenal (RMA). Procedures set forth in this FOP comply with the Geotechnical Requirements for Drilling, Monitor Wells, Data Aquisition and Reports of the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA, 1987), with the office of the Program Manager for Rocky Mountain Arsenal (PMRMA), and are consistent with procedures developed and implemented during previous field efforts at RMA.

Procedures detailed in this FOP include the following:

- Borehole drilling
- Well installation and development
- Hydraulic testing
- Geophysical methods
- Measurement/sampling of ground water, surface water, soil, sediment, and biota
- Sample custody
- Decontamination
- Field documentation

If the need for additional field activities is identified, the procedures for their implementation will be described in addenda to this document.

2.0 BOREHOLE DRILLING

All test boreholes will be drilled using a hollow-stem auger equipped drill rig, and samples will be collected using split-spoon sampling techniques. A one-foot sample will be collected every 5 feet and at each major change in lithology. Samples will be collected in clear polybutyrate liners and will be used to prepare a geologic log of each borehole. Each sample will be capped, labeled, and stored for possible future use as geotechnical samples (e.g., strength testing and sieve analysis).

During drilling, a photoionization detector (PID) will be used to monitor both the borehole and breathing zone for volatile organic compounds (VOCs). This information will be used to determine the appropriate level of personal protection for personnel. Health and safety procedures for borehole drilling are further discussed in the RIFS1 Health and Safety Plan (HSP) (HLA, 1989a).

The purpose of each boring is to assess the nature of alluvial and weathered bedrock materials (e.g., lithology, grain size, degree of consolidation), depth to competent bedrock, lithology of competent bedrock, depth to water table, and saturated thickness within the alluvial/weathered bedrock interval. Borings will be considered complete when competent bedrock is reached.

2.1 SITE PREPARATION

Prior to drilling, test boring locations will be staked, flagged, and numbered. Because the study area is located offpost in a rural residential area, both land access agreements and utility clearance will be necessary before final boring locations can be established. Land access will be negotiated by the PMRMA and the U.S. Army Corps of Engineers (COE) with HLA's assistance in identifying and contacting land owners; however, HLA personnel will contact local utilities for borehole clearance. The utility companies known to have underground pipelines, cables, etc., in the area include the following:

Public Service Co. of Colorado 33 North Main Brighton, Colorado	659-1421
Union REA 18551 East 160th Avenue Brighton, Colorado	659-0551
U.S. West Telephone	423-6700
Western Gas Supply 3202 Picadilly Road Aurora, Colorado	534-1261 366-6792

2.2 EQUIPMENT PREPARATION

All drilling and sampling equipment will be thoroughly decontaminated prior to initiating field work. Decontamination will be performed at a designated onpost decontamination pad and will consist of steam cleaning with water approved by the contracting officer's representative (COR). This procedure will also be used to decontamination all equipment, except the drill rig, between boreholes. A final decontamination of all equipment will be performed prior to removing equipment from the site upon completion of the project. A detailed description of decontamination procedures is provided in Section 14.0.

2.3 DRILLING EQUIPMENT AND TECHNIQUES

Boreholes will be drilled using a drill rig equipped with hollow-stem augers. The augers will be of a sufficient diameter (3-1/4-inch inside diameter [ID]) that a 3-inch outside diameter (OD) sampler will fit inside them. Enough auger sections will be available to drill two 70-foot boreholes. This will allow for one clean set of augers to be available for drilling while the second set is being decontaminated. The rig and augers will be equipped with a wireline system such that sampling can be achieved by lowering the sampler down the center of the augers and locking it into the lead auger section. Samples will then be collected by advancing the augers. The sampler will be extracted by "unlocking" the sampler and pulling the cable and sampler up through the augers. The polybutyrate sample liner containing the soil core will be extracted from the sampler by laying the sampler on its side, removing the top and bottom of the sampler, and

separating the sampler halves. After the liner is removed from the sampler, the liner will be capped, the caps will be taped on, the liner will be labeled with appropriate information, and the samples will be stored. A lithologic log of each borehole will be prepared in the field.

Air emissions from test borings will be monitored during drilling operations using either an organic vapor analyzer (OVA) and/or a PID. Breathing zone and borehole readings will be recorded on the field sheet and in the bound field logbook. Breathing zone readings from these instruments will determine the level of personal protection to be used while drilling. At a minimum, rubber boots, coveralls, latex and rubber gloves, and a hard hat will be worn by all personnel near the drill rig. If breathing zone readings are above zero (background), air-purifying respirators and plastic-coated coveralls will be donned. If readings exceed 5 ppm in the breathing zone, supplied-air respirators will be employed.

2.4 DRILLING AND SAMPLING PROCEDURES

Specific drilling and sampling procedures will be as follows:

1. Set up rig at staked and cleared borehole location.
2. Record location, date, time, and other pertinent information on boring log form.
3. Place 1-foot polybutyrate sample liners cut to specification into core barrel (sampler).
4. Commence augering and sampling according to the following sequence: Sample 0-1 feet, auger 1-4 feet, sample 4-5 feet, auger 5-9 feet, and sample 9-10 feet, etc. Each predetermined sampling interval will be cored in 1-foot runs to ensure acceptable sample recovery. A center plug will be placed in the lead auger section during nonsampling auger advancement.
5. At the completion of each coring interval, the core barrel will be removed from the borehole and opened.
6. The 12-inch sample liners will be removed, capped with plastic caps, and sealed with tape.
7. Each sample liner will be marked with an arrow pointing to the top end, the boring number, and depth interval. A label giving the same information as well as the project name and number, the date, and the sampler's initials will be attached to the liner.
8. For each additional 1-foot-depth increment to be cored, a clean polybutyrate liner will be placed in a clean core barrel.

9. The boring is considered complete when competent bedrock is reached. A sample will be collected to confirm that competent bedrock has been encountered.

10. All samples will be transported to the support facility, and the samples from each boring will be placed in core box(es) for storage. Each core box will be labeled according to contents and will be transported to the sample storage area designated by PMRMA.

11. The boring stake will be left in the ground adjacent to the borehole, and a board will be placed over the hole until it has been grouted.

12. All boreholes greater than 1 foot in depth will be grouted with a cement-bentonite grout the same day of construction. Grouting procedures are detailed in Section 2.5.

13. Upon completion of each boring, the augers and other downhole equipment will be decontaminated. This decontamination will be accomplished by transporting the downhole equipment to the designated onpost decon pad.

14. Enough augers and core barrels will be available such that one set may be in use while a second set is being decontaminated.

15. At the end of the working day, personnel and all equipment except the drill rig will proceed to the decontamination pad, where decontamination procedures will be initiated.

2.5 BORING ABANDONMENT

Each soil boring greater than 1 foot in depth will be sealed by grouting on the day the boring is completed. Borings 1 foot in depth or less will be backfilled with native soil. For borings located in cultivated areas, this depth will be increased to 3 feet. The grout will be composed of 20 parts cement to one part bentonite with enough water (COR-approved) for a pumpable mixture. For borings greater than 20 feet deep, the grout will be pumped through a tremmie pipe placed at the bottom of the boring. The grout will be pumped until undiluted grout flows to within 1 foot of ground surface. For borings shallower than 20 feet, the grout will be poured in from ground surface. Before the grout cures, the borehole location stake will be set into the grout. Grout settlement will be inspected after 24 hours, and depressions will be filled to within 1 foot of the surface with additional grout of approved composition. After grouting is completed and the grout has cured, the top of the boring will be backfilled with native soil material, as described above.

2.6 SAMPLE LOGGING

Borings will be logged lithologically by the HLA field geologist. Data will be recorded on boring log forms and will include the boring number, location, date, drilling equipment, driller's name, method of sampling, sample depth, and soil descriptions. Soils will be classified according to the Unified Soil Classification System illustrated in Figure 2.1. All equipment and procedures will conform to American Society for Testing and Materials (ASTM) standards. Copies of boring logs will be submitted to PMRMA upon completion of the boring.

2.7 CORE STORAGE

After the samples have been logged, sample liners will be sealed with plastic caps. The cores will be stored in core boxes in a designated onpost building in the South Plants area. Storage will be maintained such that samples are readily accessible.

2.8 SURVEYING

The boring locations and ground-surface elevations of borings will be surveyed by a surveyor registered in the State of Colorado. For each boring, the boring number, corresponding map coordinates and elevation, and date of measurement will be recorded in the field logbook. The data will be transmitted to PMRMA upon completion of surveying.

MAJOR DIVISIONS					TYPICAL NAMES
COARSE-GRAINED SOILS MORE THAN HALF IS COARSER THAN NO. 200 SIEVE	GRAVELS MORE THAN HALF COARSE FRACTION IS LARGER THAN No. 4 SIEVE SIZE	CLEAN GRAVELS WITH LITTLE OR NO FINES	GW		WELL GRADED GRAVELS WITH OR WITHOUT SAND, LITTLE OR NO FINES
			GP		POORLY GRADED GRAVELS WITH OR WITHOUT SAND, LITTLE OR NO FINES
		GRAVELS WITH OVER 12% FINES	GM		SILTY GRAVELS, SILTY GRAVELS WITH SAND
			GC		CLAYEY GRAVELS, CLAYEY GRAVELS WITH SAND
	SANDS MORE THAN HALF COARSE FRACTION IS SMALLER THAN NO. 4 SIEVE SIZE	CLEAN SANDS WITH LITTLE OR NO FINES	SW		WELL GRADED SANDS WITH OR WITHOUT GRAVEL, LITTLE OR NO FINES
			SP		POORLY GRADED SANDS WITH OR WITHOUT GRAVEL, LITTLE OR NO FINES
		SANDS WITH OVER 12% FINES	SM		SILTY SANDS WITH OR WITHOUT GRAVEL
			SC		CLAYEY SANDS WITH OR WITHOUT GRAVEL
FINE-GRAINED SOILS MORE THAN HALF IS FINER THAN NO. 200 SIEVE	SILTS AND CLAYS LIQUID LIMIT 50% OR LESS		ML		INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTS WITH SANDS AND GRAVELS
			CL		INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, CLAYS WITH SANDS AND GRAVELS, LEAN CLAYS
			OL		ORGANIC SILTS OR CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS LIQUID LIMIT GREATER THAN 50%		MH		INORGANIC SILTS, MICACEOUS OR DIATOMACIOUS, FINE SANDY OR SILTY SOILS, ELASTIC SILTS
			CH		INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
			OH		ORGANIC SILTS OR CLAYS OF MEDIUM TO HIGH PLASTICITY
HIGHLY ORGANIC SOILS			Pt		PEAT AND OTHER HIGHLY ORGANIC SOILS

UNIFIED SOIL CLASSIFICATION - ASTM D2487-85

Prepared for: **U.S. Army Program Manager's Office For Rocky Mountain Arsenal** **Commerce City, Colorado**	Figure 2.1 UNIFIED SOIL CLASSIFICATION SYSTEM

3.0 MONITORING-WELL INSTALLATION AND DEVELOPMENT

3.1 DRILLING

Monitor wells will be drilled using a combination of auger, rotary wash, and air drilling techniques, depending on the type, diameter, and total depth of the well. Techniques and procedures associated with the drilling program will be consistent with guidelines set forth in the USATHAMA Geotechnical Requirements (USATHAMA, 1987).

3.1.1 Equipment Preparation

Drilling equipment, including drill rods, augers, samplers, tools, and water tanks, will be steam cleaned prior to arrival at RMA and washed with COR-approved water before arrival at each boring or well site. Well installation materials (e.g., casing, end plugs, and protector casing) will also be steam cleaned and wrapped in plastic before arrival at each well site. Water to be used in drilling, grouting, or decontamination will be obtained at a COR-approved source. Only USATHAMA-approved lubricants will be used on the threads of downhole drilling equipment. Air usage, if any, will be fully documented with equipment descriptions and oil filter specifications as described in the USATHAMA Geotechnical Requirements (1987).

3.1.2 Sampling

Alluvial soil samples will be collected using hollow-stem auger sampling techniques described in Section 2.0. Soil samples will be 1 foot in length and will be collected every 5 feet in polybutyrate tubes. The soil samples will be logged and stored in the polybutyrate tubes for future reference.

3.1.3 Drilling Procedures

The wells planned for installation under RIFS1 include 2-inch alluvial/unconfined piezometers, 4-inch alluvial/unconfined monitoring wells, and 4-inch Denver Formation monitoring wells. All alluvial/unconfined wells will be completed inside hollow-stem augers of sufficient inside diameter to provide approximately 2-inches of clearance between the inside of the augers

and the well casing. Denver Formation wells will be completed in rotary-drilled coreholes of sufficient diameter to provide approximately 2-inches of annular space surrounding the well casing. The completion interval for Denver Formation wells will be isolated from overlying strata with threaded steel conductor casing cemented in place in accordance with accepted Halliburton guidelines. The procedures used to drill alluvial/unconfined and Denver Formation wells are presented below.

3.1.3.1 Alluvial/Unconfined Wells and Piezometers

Alluvial/unconfined wells will be drilled by first completing test boreholes using the procedures described in Section 2.0. Each borehole will then be reamed using 8-1/4-inch ID hollow-stem augers. The large-diameter augers will be advanced 1 to 2 feet into competent bedrock and left in place until well installation begins.

Alluvial/unconfined piezometers will be installed in boreholes drilled and sampled to the bedrock contact using the procedures described in Section 2.0 and 6-1/4-inch ID hollow-stem augers. Borehole reaming will not be necessary for piezometer installation.

3.1.3.2 Denver Formation Wells

The drilling procedure for Denver Formation wells will include augering through the alluvium using the procedures described in Section 2.0, setting surface casing to competent bedrock, and rotary-drilling an exploratory corehole through the Denver Formation hydrogeologic zone(s) of interest. Upon completion of the exploratory corehole, the corehole will be geophysically logged using electrical resistivity, self potential, and natural gamma devices. Results of the geophysical logging will be used in conjunction with lithologic descriptions of core samples to identify the targeted completion zone(s). If more than one completion zone is proposed at a given location, the exploratory corehole will be grouted to ground surface and offset coreholes will be drilled for well installation. A monitoring well will be installed in the exploratory corehole when the uppermost Denver Formation zone is the only completion zone

proposed at a given site. The drilling procedures for single and multiple well completions are described in more detail below.

Single wells completed in the uppermost confined Denver Formation zone will be drilled by first installing 8-inch-diameter steel casing to competent bedrock. The casing will be installed within 9-1/4-inch ID hollow-stem augers and grouted in place. A grout test will be performed to determine when grout within the borehole has hardened. The test will consist of placing a small amount of grout solution in a cup, which is then submerged in water. After the grout has hardened, a rotary drill rig will be used to advance the hole into bedrock. The hole will be drilled using COR-approved water and continuously cored using NQ core (2.98-inch diameter). The corehole will then be reamed using a 7-7/8-inch diameter drill bit. Core samples will be extracted, labelled, and logged in the field and stored in a designated location onpost.

The drilling procedure used for multiple well completions will include installing 8-inch-diameter PVC surface casing to competent bedrock as described above and NQ coring and reaming to the base of the lowermost proposed completion interval. After the pilot hole has been descriptively and geophysically logged and completion intervals have been determined, the pilot hole will be grouted to ground surface. A new hole will be drilled approximately 20 feet from the pilot corehole for each proposed monitoring well. These holes will be drilled using a rotary drill rig with drilling fluid consisting of COR-approved water. Approximately 8-inch-diameter steel surface casings will be installed to competent bedrock and grouted in place when drilling wells to be completed in the uppermost Denver Formation zone. Approximately 12-inch-diameter steel surface casings will be installed to competent bedrock, and 8-inch-diameter steel casings will be installed to the base of the uppermost Denver Formation zone when drilling wells to be completed in the next deeper zone. This procedure of telescoping casing will be continued when drilling wells to subsequently deeper zones.

3.1.3.3 Arapahoe Formation Wells

Arapahoe Formation Wells will be drilled using a combination of mud rotary and air rotary drilling methods. Mud rotary techniques utilizing of a mixture of COR-approved water and bentonite, will be used to advance the hole from the ground surface to the base of the Denver Formation. Air rotary techniques will be used to advance the hole from the base of the Denver Formation to the desired completion depth within the Arapahoe Formation.

All drill cuttings and fluids generated while drilling through alluvium and the Denver Formation will be containerized onsite. Drill cuttings and fluids generated while drilling within the Arapahoe Formation will be handled in accordance with the field screening and drumming procedures described in Section 16.0. All drilling wastes will be transported daily to the Weston Services waste handling facility located in Section 6, Building 785.

Grout composed of 10 parts cement to 1/2 part bentonite by weight with a maximum of 10-gallons of approved water per 94-pound bag of cement will be used to seal conductor casings placed during drilling. A mud balance will be used to verify the correct density of the grout.

The procedures to be followed during drilling are presented below:

1. A 15-inch diameter hole will be drilled using a mud rotary system to the base of the unconfined aquifer.

2. A 12-1/4-inch diameter, 188-gauge black steel conductor casing will be set from the ground surface to the base of the unconfined aquifer. The conductor casing will be pressure grouted into place using a plug inserted at the base of the casing and a pressure pump. Grout will be pumped until undiluted grout is observed at the ground surface. A sample of the grout mixture will be placed in a cup and submerged in water to check for setup time (approximately 12 to 24 hours).

3. An 11-inch diameter hole will drilled using a mud rotary system through the grout plug and to the base of the Denver Formation.

4. An 8-1/4-inch diameter, 188-gauge black steel casing will be set from the ground surface to the base of the Denver Formation. The casing will be pressure grouted into place using the grout emplacement method described above. A cement bond log then will be run to assess the integrity of the second conductor casing.

5. A 7-7/8-inch diameter hole will be drilled using an air rotary system through the grout plug to the completion depth, expected to be to the base of the Upper Arapahoe Formation. If the cuttings are too heavy to be air circulated, mud circulation will be used.

6. An SP-Gamma-Resistivity log will be run through the Arapahoe portion of the hole.

Well Installation

Installation of all Arapahoe wells will begin within 12 hours of borehole completion. Once installation has begun, no break in the installation process will be made until the well has been grouted and the protective casing installed. All materials used in well construction will be approved by PMRMA prior to use.

The procedures to be used during well installation are presented below:

1. Well screen will be commercially fabricated, continuous wound, 20-slot (0.020-in) stainless steel having an ID of 4-inches. The screen will be selectively set adjacent to the sand units in the Arapahoe Formation. Mild steel (low carbon) blank casing will be used between screened intervals and as a riser above the filter packed interval.

2. After placement of the screen and casing, the borehole will be flushed through the screen with COR approved water to clear the mud from the annulus.

3. The annular space between the casing/screen assembly and the formation will be filled with a sand filter pack to a depth of no less than 5 feet above the well screen. A 1-pint sample of filter pack material will be submitted to the PMRMA for approval prior to use on site. It is expected that the material used will be 8 to 12-mesh silica sand or coarser from Colorado Silica Sand, Inc. The filter pack will be allowed to free fall through an appropriately sized tremie pipe. If necessary, COR-approved water will be added to prevent bridging of the sand. The volume of this water will be recorded for subsequent removal during well development. The depth to the top of sand will be measured after the minimum volume has been added to insure that the required depth has been reached. Fine sand may be added above the sand pack to form a seal below the bentonite.

4. A bentonite seal approximately 10 feet thick will be placed above the sandpack. The thickness will be measured immediately after placement, without allowance for swelling. The seal will be composed of drop placed commercially available bentonite pellets or a granular slurry which will be pressure pumped into place. The slurry will have a density of approximately 9.4 pounds/ gallon as measured using a "mud balance". The decision to use pellets or a slurry will be made at the site based upon the required drop depth and the conditions of the borehole walls.

5. The annular space above the bentonite seal will be grouted up to the ground surface by pumping through a tremie-pipe placed at the bottom of the interval to be grouted. The grout will be composed of cement with 5 percent bentonite by weight, and 6 to 8 gallons of water per 94 pound sack of cement.

6. The grout seal will be inspected for settlement 24 hours after placement and grout will be added, if necessary, to the level of the ground surface.

Well Completion and Testing

1. Upon completion of the well installation, the well will be developed by means of a submersible pump. A minimum of five times the volume of standing water in the well, sand pack, and annulus will be removed. If any water was added and lost during drilling or completing the well, five times this additional volume will also be removed. The well will be developed until the water is clear and as sediment-free as possible. During development a draw down test will be performed to measure the hydraulic properties of the formation. The test will run for at least 2 hours and a static water level shall be recorded upon completion.

2. A ground-water sample will be collected prior to disinfection.

3. Pump equipment will be installed and the entire system disinfected according to State regulations with a 100 ppm bromine solution.

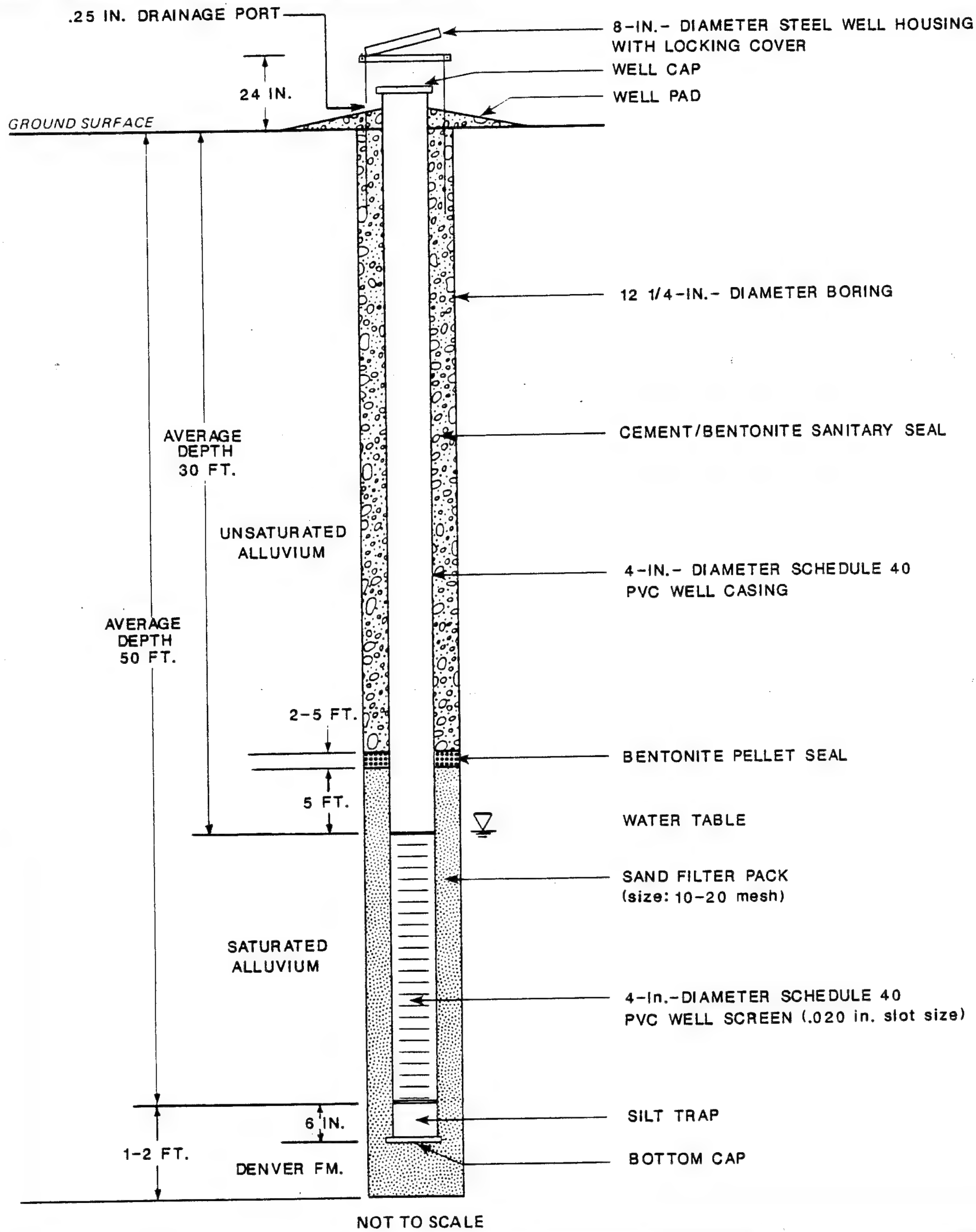
4. After sufficient time has elapsed (minimum of 3 hours) the entire system will be flushed and a sample will be collected and submitted for chemical analysis in accordance with the analytes defined in the QA Plan (HLA, 1989b).

3.2 WELL CONSTRUCTION

Monitoring wells and piezometers will be constructed using the procedures developed in accordance with USATHAMA guidelines and utilized during previous RMA onpost and offpost investigations. Generalized construction diagrams for alluvial/unconfined monitoring wells and piezometers are shown in Figures 3.1 and 3.2. Generalized construction diagrams for monitoring wells completed in the uppermost Denver Formation zone and the next underlying zone are shown in Figures 3.3 and 3.4. The components associated with the installation of all new monitoring wells and piezometers are described in the following subsections.

3.2.1 Well Screens, Casings, and Fittings

All wells will be constructed using Schedule 40 PVC casing and commercially fabricated well screen. Casing sections and well screens will be attached by nonrestrictive threaded-type joints. Casing diameters will include 4-inch ID for all monitoring wells and 2-inch ID for piezometers. Alluvial/unconfined and Denver Formation wells and piezometers will have a screen slot size of 0.020-inch (20-slot). Arapahoe Formation wells will be constructed using continuous-wound stainless steel well screen of suitable slot size.



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For Rocky Mountain Arsenal
Commerce City, Colorado

Figure 3.1
GENERALIZED CONSTRUCTION FOR STANDARD ALLUVIAL/UNCONFINED MONITORING WELL

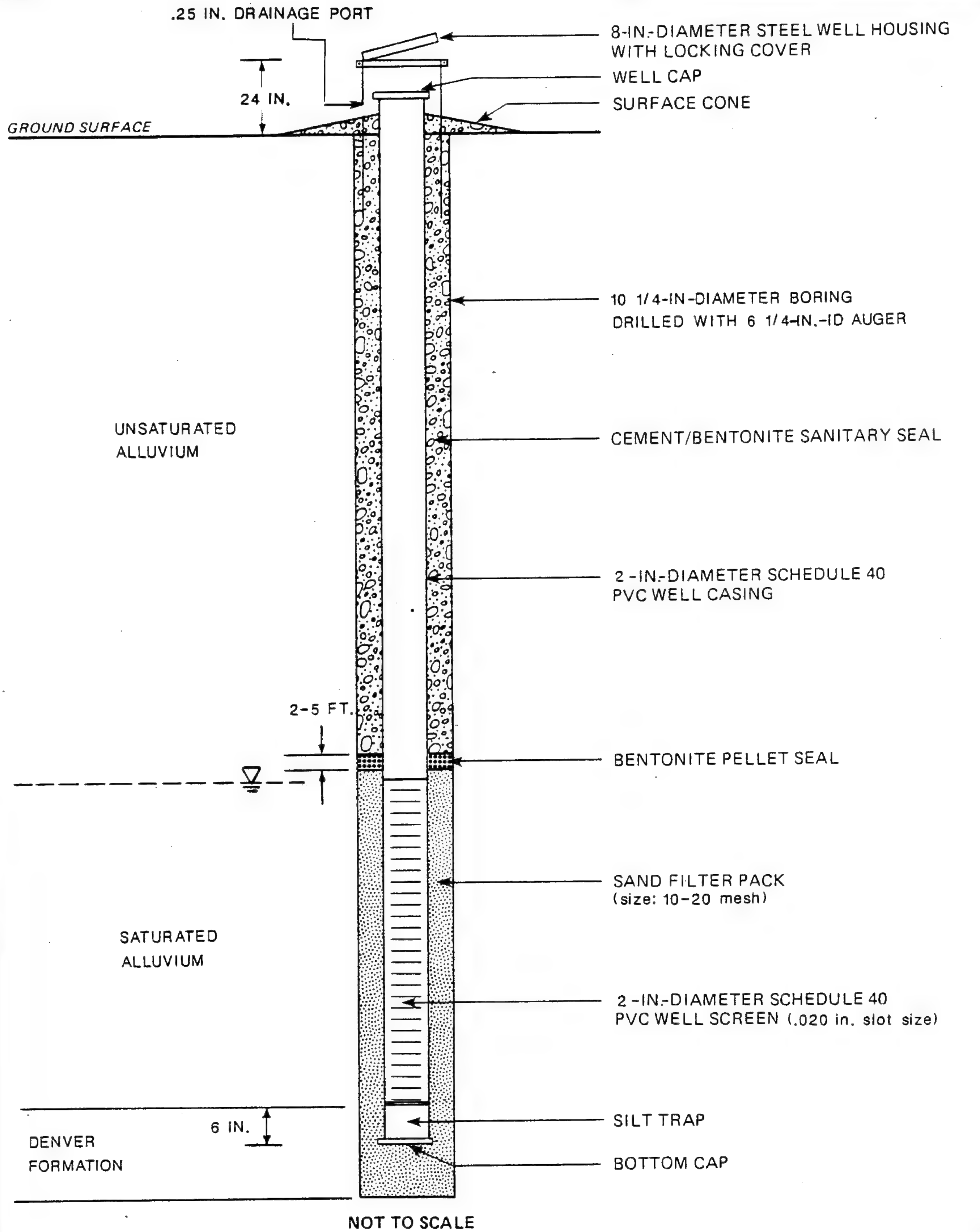

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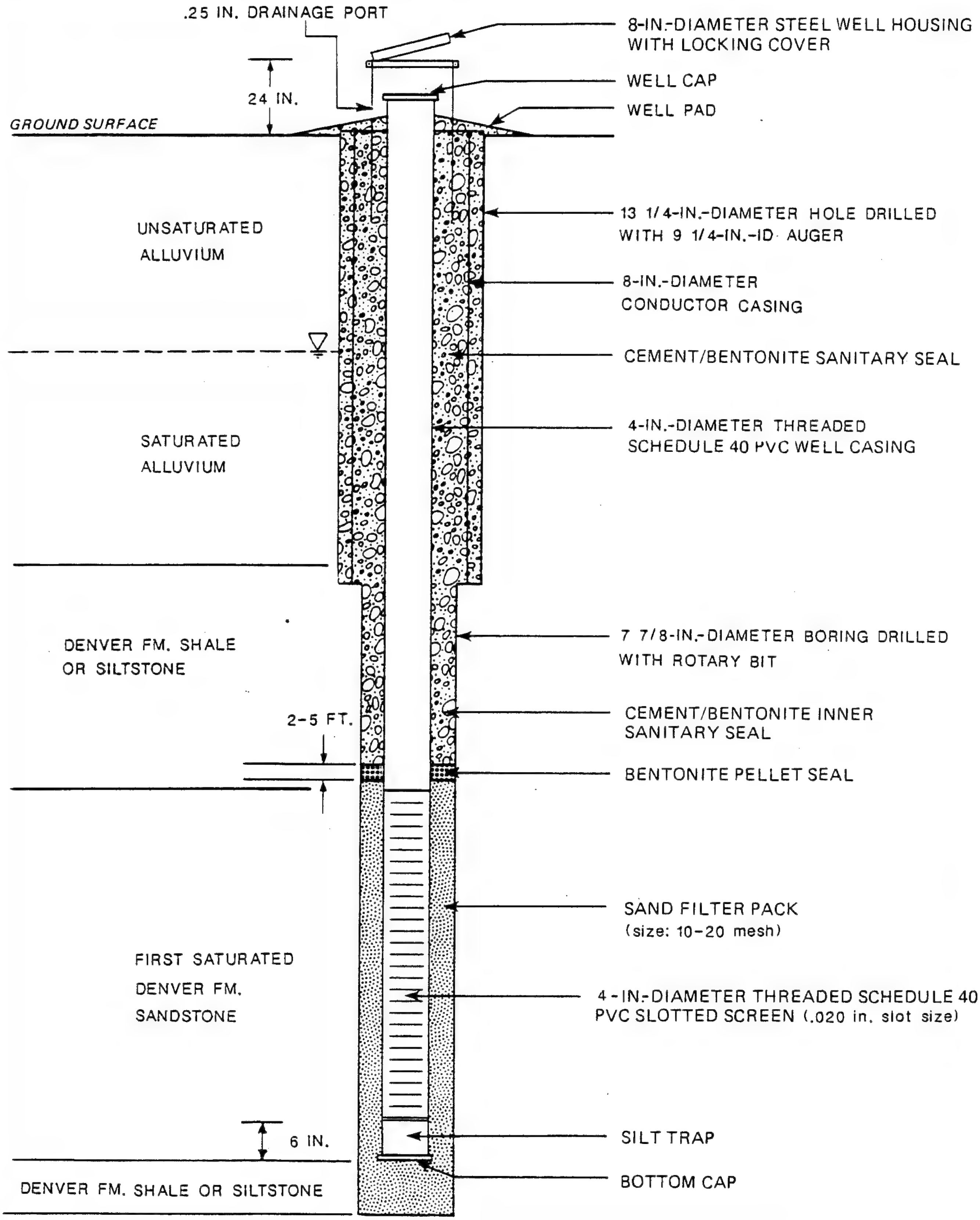
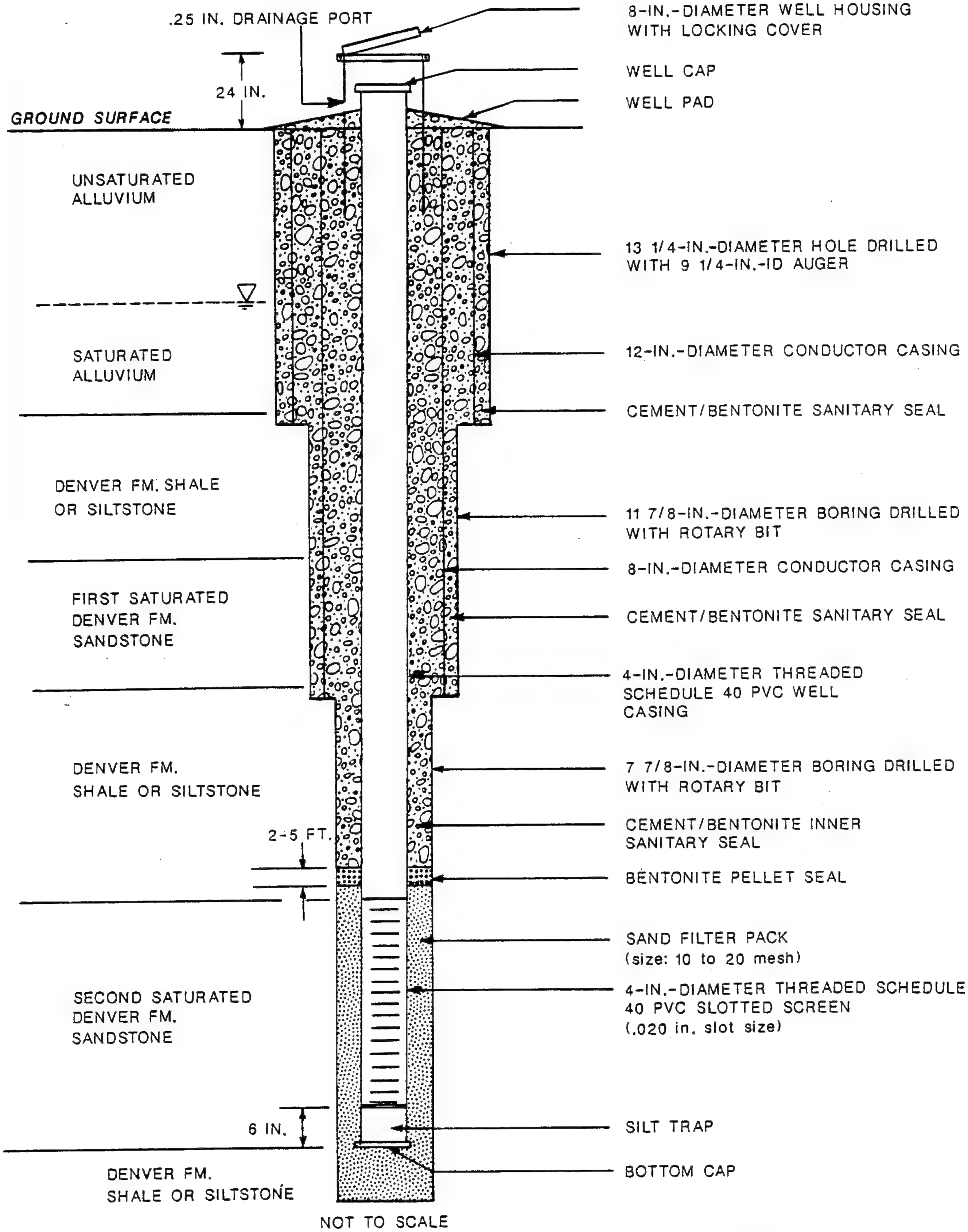
Figure 3.2
GENERALIZED CONSTRUCTION FOR ALLUVIAL/UNCONFINED PIEZOMETER



NOT TO SCALE

Prepared for: **U.S. Army Program Manager's Office For Rocky Mountain Arsenal** **Commerce City, Colorado**	Figure 3.3 GENERALIZED CONSTRUCTION FOR DENVER FORMATION FIRST SANDSTONE MONITORING WELL



Prepared for:	Figure 3.4
U.S. Army Program Manager's Office For Rocky Mountain Arsenal Commerce City, Colorado	GENERALIZED CONSTRUCTION FOR DENVER FORMATION SECOND SANDSTONE MONITORING WELL

Alluvial/unconfined wells and piezometers will be screened from the top of competent bedrock to the water table; however, in some instances modifications may be necessary based on shallow water table conditions. Denver Formation and Arapahoe Formation wells will be screened across the hydrogeologic zone(s) of interest determined by geophysical logging results and lithologic description of core samples. Prior to installation, all screens and casing materials will be decontaminated by steam cleaning, allowed to air dry, and stored in plastic. All material will be clean and free of foreign matter (adhesive tape, labels, soil, grease, etc.) and will be washed with COR-approved water. The casing will extend 2 feet above ground surface, and casing tops will be fitted with oversized hand-removable caps.

Stainless steel well centralizers will be attached by stainless steel clamps and will be used only on blank casing at 50-foot intervals between ground surface and the top of the sand pack. Boreholes containing excessively thick or particulate-laden fluid that might preclude or hinder well installation will be purged with COR-approved water or bailed with a sand pump prior to installation.

3.2.2 Filter Pack

The annular space between the casing/screen assembly and the formation will be filled with a gravel or sand filter pack to a depth of no less than 5-feet above the well screen, although this may be modified based on shallow water table conditions. A 1-pint sample of filter pack material will be submitted to PMRMA for approval prior to use on the site. It is expected that the material used will be 10- to 20-mesh silica sand from Colorado Silica Sand, Inc. If water is needed to facilitate placement of the gravel/sand pack, a minimal amount of COR-approved water will be used. The volume of this water will be recorded for subsequent removal during well development.

3.2.3 Bentonite Seal

A bentonite seal 5 feet thick will be placed above the sand pack except where shallow ground-water table conditions prevent this. In this case, a seal of no less than 2 feet thick will be

installed. The thickness of the bentonite seal will be measured immediately after placement, without allowance for swelling. The seal will be composed of commercially available bentonite pellets. This material will meet USATHAMA specifications and be approved by PMRMA prior to use on the site.

3.2.4 Grout Seal

Annular spaces in alluvial monitoring wells will be grouted by pumping through a tremie pipe placed at the bottom of the interval to be grouted or by gravity placement within the hollow-stem auger. The grout will be composed of cement with 5 percent bentonite by weight and 6 to 8 gallons of water per 94-lb. bag of cement. These materials will meet USATHAMA specifications and be approved by PMRMA prior to use on the site. The grout seal will be inspected for settlement 24 hours after placement and grout will be added, if necessary, to the level of ground surface.

3.2.5 Protective Casing

A lockable protective casing will be set into the grout seal surrounding offpost wells. The casing will be constructed from 8-inch-diameter steel pipe, 5-feet long, with a lid capable of being locked. Oversize casings of 10-inch diameter will be installed at the 6-inch dual purpose wells. Protective casings will be cleaned of all foreign matter prior to use, will be placed 3 feet into the grout, and will extend 2 feet above ground surface. The offpost wells will be padlocked at the time of installation of the protective casing. After installation, the outside of the protective casing will be painted white, and the well identification will be painted black. All painting will be done with a paintbrush and not with an aerosol can. No solvents will be used in the vicinity of the well casing.

Aggregate cement will be poured to a depth of approximately 0.5 feet above ground surface in the annular space between the protective well casing and the well casing. A circular 4-foot-diameter pad approximately 0.5 feet thick will be poured outside the protective casing and will

slope away from the well to provide surface-water drainage. A 0.25-inch-diameter drainage port will be drilled in the protective casing immediately above the level of the cement collar.

3.3 WELL DEVELOPMENT

All monitoring wells will be developed at least two weeks prior to sampling. Wells will be developed with either a submersible pump or a bottom-discharge bailer, with or without a surge block. A minimum of five times the volume of standing water in the well, sand pack, and annulus will be removed. If any water was added and lost during drilling or completing the well, five times this volume will also be removed. The wells will be developed until the water is clear and as sediment-free as possible to ensure that any remaining sediment obstructs no more than 5 percent of the total screen length.

Measurements obtained and recorded in the field will include static water levels before and after development and pH, temperature, and conductivity measurements before, during, and after development. For each well, a 1-pint sample of the last water to be removed during development will be collected and retained. Appropriate forms and other pertinent data will be submitted to PMRMA or an authorized representative upon completion of well development.

3.4 WELL IDENTIFICATION

Upon completing the installation of the well, the well location, elevation of ground surface, and the top of the well casing will be surveyed. Well locations will be accurate to within 3 feet using State Plane and Universal Transverse Mercator (UTM) coordinates. Elevations will be surveyed to within 0.1 foot using the National Geodetic Vertical Datum of 1929.

Well identification numbers, map coordinates, and elevations will be recorded in a field logbook and will be submitted to PMRMA or an authorized representative at the end of the program. A metal tag stamped with these data will be permanently attached to each protective casing.

3.5 WELL ABANDONMENT

The abandonment of well sites may be required if the useful purpose of the site or installation is deemed unacceptable. The abandonment of wells will be approved by the Contracting Officer prior to any casing removal, sealing, or backfilling. Once determined, the borehole or monitoring well to be abandoned will be sealed by grouting from the bottom of the borehole/well to ground surface. This will be conducted by placing a grout pipe (tremie pipe) to the bottom of the borehole/well (i.e., to the maximum depth drilled/bottom of well screen) and pumping grout through the grout pipe until undiluted grout flows from the borehole/well at ground surface. Any open or ungrouted portion of the annular space between the well casing and borehole will also be grouted in the same manner. After grout placement, the grout pipe, augers, and well casing will be removed. When conditions permit, the grout placement and casing removal may be completed incremently so as to constantly maintain 10 feet of grout within the borehole.

After 24 hours, the abandoned site will be checked for grout settlement. That day, any settlement depression will be filled with grout and rechecked 24 hours later. This process will be repeated until firm grout remains within 1-3 feet of ground surface.

3.6 DISPOSAL OF CUTTINGS AND WATER

Drilling, installation, development, and testing activities will generate borehole materials and fluids that may be contaminated. These materials will be containerized in truck-mounted storage tanks or 55-gallon plastic drums and transported from the field to designated storage or disposal areas at RMA. All wastes generated during the drilling program will be handled in accordance with the procedures described in the EPA waste handling guidance letter for RMA (EPA, 1985). A more thorough discussion of waste disposal and treatment procedures is contained in Section 16.0 of this document.

4.0 HYDRAULIC TESTING

The following describes the procedures necessary for performing long-term aquifer tests, should such testing be desirable during the investigation.

4.1 EQUIPMENT

To perform a long-term aquifer test, a pump having sufficient capacity to produce significant water-level drawdowns will be installed in the well to be pumped. It is recommended that two electric submersible pumps (2 HP and 5 HP) be available on site. The actual pump size used during a long-term test will depend on the discharge rates observed during well development and step-drawdown testing. The 5 HP pump will have the capacity to produce up to 250 gpm with 50 feet of lift. Flow rates will be controlled by a manual control valve located on the discharge line.

During testing, water levels will be measured by electrical pressure transducers in the pumping and observation wells. A multiple-channel data logger with internal memory will be used for data acquisition. The data logger will record downhole pressures and temperatures from the transducers and flow rates from the discharge flow meter. During pumping tests, water levels will be periodically measured in all wells using electric probes to corroborate the transducer readings. This will allow for corrections to be made to the transducer readings should electrical drift be observed in the transducer signals. Barometric pressures will be obtained from the nearest weather station capable of providing this information.

The following schedule of water-level measurements will be used in all wells containing pressure transducers:

0 -	10 minutes;	every	30 seconds
10 -	20 minutes;	every	1 minute
20 -	60 minutes;	every	2 minutes
60 -	120 minutes;	every	5 minutes
120 -	240 minutes;	every	10 minutes
	>240 minutes;	every	30 minutes

This schedule will be initiated at the beginning of pumping and recovery of long-term aquifer tests and at the beginning of each step of step-drawdown tests.

Prior to testing, electric water-level probes will be calibrated against a steel tape. If necessary, a correction equation will be developed for each probe so that the observed measurement can be converted to the true depth to water. During testing, the water level in each well will always be measured with the same probe.

Discharge water obtained from both step-drawdown tests and long-term tests will be temporarily collected in storage tanks located at the test site. Water in the collection tanks will then be pumped into tank trucks and transported to a location designated by PMRMA for disposal. For planning purposes it is anticipated that several 20,000 gallon capacity tanks and at least two large-capacity tanker trucks must be available for each test.

Initial site activities for aquifer tests will include installing the electric submersible pump in the extraction well and setting up the electrical cables, discharge control valve, flow meter, discharge line, and collection tanks. Electrical power will be supplied by a portable gasoline or diesel generator.

4.2 FIELD PROCEDURES

This section describes field procedures for performing aquifer tests.

4.2.1 Step-Drawdown Tests

The general procedure for performing step-drawdown tests is as follows:

1. Prior to initiation of pumping, monitor water levels in the pumping well and the close-in observation well until static conditions are attained or until the long-term trend in water-level variation is defined. In any case, pre-test monitoring will be performed for a minimum period of two hours before the test.

2. Operate the submersible pump and increase flow rate until the pumping water level is at approximately 25 percent of available drawdown. Flow rate will be modified by adjusting the control valve on the discharge line. Available drawdown is defined as the vertical distance between the initial static water level in the well and the pump intake. The percent drawdown criterion is used only at the beginning of the step to determine a target discharge rate. Once this discharge rate is determined, that rate will be held constant for the remainder of the step regardless of drawdown.

3. Continue pumping at this rate for one hour (Step 1). During this step, flow rates and water levels in the pumping well and close-in observation well will be measured according to the schedule previously discussed, with initial water level measurements every 30 seconds.

4. Increase flow rate so that the pumping water level is at approximately 50 percent of available drawdown. Continue pumping at this constant rate for one hour (Step 2). Water levels and flow rates will be measured according to the specified schedule (i.e., initial water levels every 30 seconds).

5. Increase flow rate so that the pumping water level is at approximately 75 percent of available drawdown. Continue pumping at this constant rate for one hour (Step 3). Water levels and flow rates will be measured according to the specified schedule.

6. Increase flow rate so that the pumping water level is at approximately 90 percent of available drawdown. Continue pumping at this constant rate for one hour (Step 4). Water levels and flow rates will be measured according to the specified schedule.

7. Discontinue pumping and initiate the recovery period. During recovery, water levels will be measured in the pumping well and the close-in observation well according to the specified schedule with initial water level measurements every 30 seconds.

Based on the step-drawdown test, a flow rate for the long-term test will be determined. This optimal pumping rate will result in a pumping water level predicted to range from 70 to 90 percent of available drawdown over a period of 24 to 48 hours of continuous pumping. Based on the preliminary aquifer parameter values determined from the step-test, calculations will be performed to verify that the water level inside the pumping well will not likely reach the pump intake for the duration of long-term test. In addition, the preliminary aquifer parameters will be used to determine optimal locations of additional observation wells to be drilled at each site for the long-term tests.

4.2.2 Long-Term Constant Rate Tests

The general procedure for performing long-term pumping tests is as follows:

1. Prior to the test, water levels in the pumping well and in all observation wells will be monitored on a periodic basis until static conditions are attained or until the long-term trend in water-level variation is defined. In any case, pre-test monitoring will be conducted for a minimum of 24 hours prior to pumping. This will be accomplished using pressure transducers in the pumping/observation wells and the data logger. Barometric pressure readings for the same time interval (and also for the actual test period) will be obtained from the nearest weather station capable of providing this data.

2. Operate the pump at a flow rate equal to the optimal pumping rate determined from the step-drawdown test. The flow rate will be set by adjusting the control valve of the discharge line. During the pumping period, water levels will be measured in the pumping well and all observation wells according to the schedule previously discussed. Flow rates will also be monitored on a periodic basis.

3. During pumping, a constant discharge rate will be maintained by periodically adjusting the control valve on the discharge line, if necessary. If it appears that the pumping water level in the extraction well will fall below the pump intake before the end of the test, a step decrease in flow rate will be made (rather than making multiple adjustments in the pumping discharge rate).

4. Constant rate pumping will be continued for 24 to 72 hours, depending on the hydraulic responses measured in the observation wells. Pumping will be extended beyond the 24-hour minimum if water-level drawdown in any of the observation wells is less than 0.5 feet. In any event, the maximum duration of pumping will be 72 hours.

5. Discontinue pumping and initiate the recovery period. During recovery, water levels will be measured in the pumping well and in all observation wells according to the specified schedule. Recovery will be monitored until 90 percent recovery is achieved or until the duration of recovery monitoring equals or exceeds the duration of pumping period, whichever is less.

4.3 AQUIFER TEST ANALYSIS

4.3.1 Field Analysis

During testing, the data logger will record discharge rates and downhole pressures/ temperatures in the pumping and observation wells. The data logger will enter this information into internal memory at all times, even when unattended. In addition, a laptop computer will be interfaced with the data logger so that site personnel can monitor flow rates and pressure measurements as they are taken. This will allow for onsite evaluation of test performance and the operation of equipment. At various times during the test, data will be downloaded from the data logger to the laptop computer for hard storage, and the resulting data files will be imported into LOTUS 1-2-3 for subsequent data reduction. The graphics capabilities of LOTUS will allow for the plotting of test data and the performance of field analyses while the test is in progress.

Step tests will be analyzed to determine (1) the efficiency of the pumping well, (2) an optimal discharge rate for the long-term test, and (3) preliminary values of aquifer parameters. Pumping well efficiency will be evaluated using the analytical procedures discussed in Jacob (1946) and Rorabaugh (1953). These methods will be used to compute parameters describing well

loss. In this context, well loss is related to the drawdown inside the pumping well resulting from nonformational effects such as turbulent flow and frictional losses in the well screen and sand pack. An optimal flow rate for the long-term constant rate test will be determined by constructing a flow rate versus drawdown performance curve based on the step test data. From this rating curve, a flow rate for the long term test will be selected which provides for an initial pumping water level at about 70 to 80 percent of the available drawdown. In addition, calculations will be performed to verify that the selected flow rate will not likely result in water levels reaching the pump intake for the duration of the long-term test.

An advantage of the proposed test strategy is that only a single close-in observation well need be available for monitoring during the step test. Water levels monitored in this observation well will provide information which will be used to evaluate preliminary values of aquifer hydraulic conductivity. This evaluation will be based on variable flow rate analyses such as those presented in Ferris, et al (1962) and Sternberg (1968). The preliminary hydraulic conductivity values will then be used at each test site to determine the optimal locations of additional observation wells for the long-term test.

Field analysis of the long-term aquifer test will be performed using semilog methods (e.g., Cooper and Jacob, 1946), which generally assume an ideal aquifer but can be modified to account for certain nonstandard responses such as those caused by hydrologic boundaries. The primary purpose of the field analyses will be to evaluate test performance and determine the ultimate duration of the pumping period. Field analyses will be performed while the test is in progress.

4.3.2 Final Analysis

Final test analysis will be completed in the office after the test is completed. If during testing, the hydraulic responses are characteristic of an ideal aquifer, test data will be analyzed using the Theis (1935) method. It is possible, however, that nonstandard (non-ideal aquifer) hydraulic responses may be observed in the observation wells. If this is the case, HLA considers that conceptual model(s) used for final analysis of pump test data should not be selected until the

observed hydraulic responses are evaluated. This is because the nature of observed response provides an indication of the types of physical mechanisms affecting the test. In selecting the appropriate models for test analysis, the following physical mechanisms will be considered:

- Delayed gravity response at the water table
- Possible existence of hydrologic boundaries
- Variations in saturated thickness
- Leakage from underlying bedrock
- Wellbore storage in pumping well
- Time lag in observation wells

In any case, the level of sophistication of the analysis will be commensurate with the overall uncertainty and utility of the test results.

5.0 GEOPHYSICAL METHODS

5.1 ELECTRICAL

The vertical distribution of resistivity in the earth may be measured directly by lowering an appropriate instrument into a borehole or indirectly by means of measurements taken at or above the earth's surface. To take measurements from the surface, electric current must be forced to flow through the earth. This can be done either by electromagnetic induction or by direct current (DC) methods, in which a steady current is injected directly into the earth through two or more electrodes.

5.1.1 Borehole Induction Logger

The EM39 provides measurement of both the electrical conductivity and magnetic susceptibility of the soil and rock surrounding a borehole using inductive electromagnetic techniques. The unit employs a coaxial coil geometry with an intercoil spacing of 50 cm to provide a substantial radius of exploration into the host material while maintaining excellent vertical resolution; measurement is unaffected by conductive borehole fluid in the borehole or by the presence of plastic casing. The instrument operates to a depth of 200 meters.

5.1.2 Soil Conductivity Measuring System

The Geonics EM34-3 is an inductive conductivity measuring system which consists of separate transmitter and receiver coils and consoles, linked by a reference cable. It can be operated with coil spacings of 10, 20, and 40 meters. If the transmitter and receiver coils are held vertically, the observed apparent conductivity represents an average value to a depth of about 25, 50, and 100 feet, respectively.

Current flowing in the transmitter coil generates an electromagnetic field, which in turn causes small electrical currents called secondary currents to flow in the ground under the instrument. The strength of these currents depends on the resistivity of the ground. These secondary currents in turn create a secondary electromagnetic field which is measured by the

receiver coil. By taking readings with different coil spacings, it is possible to determine whether the conductivity increases or decreases with depth.

The EM34-3 is calibrated to read apparent conductivity directly in millimhos per meter (mmhos/m). The EM34-3 can read apparent conductivities as low as about 0.5 mmho/m.

5.1.3 DC Resistivity

The four-electrode Schlumberger DC resistivity array is proposed for this study. Current I is injected into the earth through electrodes A and B, and the voltage difference, V, generated by this current flow is read between electrodes M and N. By increasing the current electrode spacing AB while holding MN constant, current is forced to flow more deeply into the earth, and resistivity information is obtained from greater depths. This procedure is called a vertical electric sounding (VES).

VES measurements are made using a modular system designed and fabricated by HLA. The transmitter system power supply consists of a series of batteries that provide a selectable voltage range of 12 to 2500 VDC, with maximum current capability of about 20 amps. The current is controlled by a high-capacity manual switch, and is measured on a Beckman model TECH 350 digital multimeter with a maximum range of 20 amps and a minimum resolution of 0.1 microamps.

The receiver voltage across the MN electrodes is read on a Fluke Model 8050A-01 digital multimeter, with an input impedance of 10 megohms and a minimum resolution of 10 microvolts. The voltage and current readings on the multimeters can be "frozen" for later recording.

5.2 PILOT BOREHOLE LOGGING

A suite of three borehole geophysical logs will be run in pilot boreholes for all new Denver Formation monitoring wells. This suite will consist of electrical resistivity, self potential (SP), and natural gamma logs. The purpose of running this log suite is to identify permeable (sand) zones within the Denver Formation. Once permeable zones are identified, wells will be com-

pleted in the appropriate intervals. These logs also will prove useful in geologic correlation of units within the Denver Formation.

The three logs listed above were chosen because they measure properties that can be used in distinguishing lithologies. The resistivity log is typically the most accurate of the three, producing a strong response from sandy/permeable intervals. The natural gamma log measures natural radioactivity, which is typically higher in clays than in sands. The SP log response is a rough indicator of formation permeability. Used together, these three logs provide a good deal of information on lithology and permeability.

For each method, the logging tool is lowered into the borehole on a wireline and logging is performed on the trip out of the hole. Data are digitally recorded on magnetic tape and can be subsequently played back, edited, and plotted at any convenient scale. The gamma log can be run in an open or cased hole with or without fluid present in the borehole. This allows the hole to be logged from total depth to the surface. The SP and resistivity logs can only be run in open holes where fluid is present; thus, they can be run in the Denver Formation, but not in the alluvial interval where conductor casing is installed.

Logging and wireline tools will be decontaminated before logging a hole, between holes and after logging operations are finished. Decontamination procedures are described in Section 14.3.

6.0 WATER-LEVEL MEASUREMENT

Water levels will be measured at the time water samples are collected prior to well purging. A separate water-level measurement event may also be performed at some time if point-in-time hydraulic data are desired. The procedure for collecting water-level measurement data is summarized below:

1. Zero the precalibrated photoionization detector (PID) to ambient air conditions. With respirators on and from an upwind direction, uncap well and record background and casing headspace readings with a PID. Respirators may be removed if PID values are at background levels within the breathing zone around the well head. Respirators need not be donned when approaching the well if PID readings and analytical data from the previous two sampling events show no elevated contaminant levels.

2. Record well number, date, pertinent observations (e.g., weather, well condition) station elevation, casing diameter, screened interval, and field instrument identification. Note whether the well has a vent.

3. Record well stickup, depth to water, and total well depth. All measurements will be made from a measuring point marked at the top of casing (TOC). Compare measured values with previous measurements; investigate and document any discrepancies. Measuring devices used to obtain water level and total depth measurements will be decontaminated with deionized (DI) water. All notations are recorded in duplicate on the water-level measurement form (as described in Section 15.0) and in a bound field notebook.

4. Record the well number, date, time, and initials of field personnel taking measurements.

5. Measure the length of the riser stickup from the ground surface to a measuring point marked at the TOC and record the length to the nearest one-tenth foot. Measure and record casing diameter in inches.

6. Insert the water-level indicator probe until it reaches water. Measure the depth to water from the same measuring point at the TOC and record the value to the nearest one-hundredth foot.

7. Measure the total depth of the well in the same fashion.

8. Retrieve the water-level indicator probe and rinse the cable and probe with deionized water as they are withdrawn from the well.

9. Record the make and model of the water-level indicator used.

10. Compare total depths, water level, and stickup to previous measurements (where applicable) and values listed in the RMA Well Summary Report (D.P. Associates, 1987). If discrepancies are observed, second measurement verifications will be performed and documented as such.

11. Record well conditions (cracked casing, missing cap, subsidence features, etc.) and any other pertinent observations.

12. Insure that all labels and flagging clearly indicate the well location and the well number.
13. Police the area to assure that all equipment and materials have been retrieved, no litter is left, and the well cap is secure.

7.0 GROUND-WATER SAMPLING

Ground-water sampling procedures will comply with those developed and employed under previous investigations including Task 44 (ESE, 1988) and the Comprehensive Monitoring Program (Stollar, 1988). The management structure for coordination of field personnel performing ground-water monitoring activities will include a field supervisor, a safety officer, and two-person field teams. One member of each field team will be designated as the field team leader and will be responsible for all tasks completed by the team. Field team leaders will be selected from personnel who have previous sampling experience at RMA. The daily activities of all field teams will be managed by the field supervisor. In addition, the field supervisor will review all data collected, ensure that chain-of-custody records are maintained, and supervise sample collection, handling, packaging, and shipment.

7.1 EQUIPMENT

At the beginning of each monitoring program, field team leaders will be issued field kits containing instruments, sampling equipment, calibration standards, and operator's manuals, as well as copies of the appropriate work plan, Field Operations Plan (FOP), QA Plan, HSP and the RMA Section Plots and Well Summary Report (D.P. Associates, 1987). These kits will include a submersible pump, a stainless steel bailer system (including 1-foot threaded bailer sections and a Teflon bottom-decanting device), a compressor and/or generator, a tank for containing well and decontamination (decon) water and a 4-feet x 2-feet x 2-feet metal storage locker. Each locker will be equipped with the following:

1. pH, conductivity, and dissolved oxygen meters as well as a complete set of spare probes, cables, and batteries for each instrument and a flow cell in which to take measurements
2. Alkalinity titration kits
3. Calibration standard solutions and detailed calibration procedure instructions
4. Two 100-ml wash bottles and a set of two 500-ml, two 250-ml, and two 100-ml beakers
5. Water-level measuring device (e.g., Solinst)
6. 25-foot steel engineer's tape

7. Plastic sheeting

8. 100 spare gloves

9. 50 plastic bags

10. 1,000 feet of 1/4-inch nylon rope

11. Filtration kit (peristaltic pump, filter holder, replacement hoses, filters, 50 ml of dilute nitric acid, and pH indicator paper)

12. 50 ml of 1:1 sulfuric acid for nitrate preservation

13. 50 ml of dilute NaOH solution for cyanide preservation

14. Complete set of spare sample fraction containers

15. Detailed sample procedure plan taped in plastic to the inside lid of the locker

Each field kit will be restocked as necessary by the field team leader following each day of sampling. Additional field equipment (deionized water, decontamination wash basins) will be stocked as needed by each field team. At least one complete set of spare field instruments will be kept readily available at the support facility.

7.2 PROCEDURES

Prior to the start of field work, the field supervisor will ensure that all personnel have been fully trained in the operation of all field equipment and that each team member understands the field procedures described in any Work Plan and in the FOP. In the event that procedure modifications are made or additional equipment or instrumentation are to be used, the field supervisor will schedule training sessions introducing these modifications or equipment changes to the field personnel as well as providing written instructions.

All data collected during a ground-water monitoring program will be recorded on pre-printed field data sheets and in bound field notebooks. When not in use, all field notebooks will be maintained by the field supervisor and kept in a secured area at the site support facility. Notebooks will be checked out by the field supervisor to the field team leaders on a daily basis. A complete discussion of field documentation may be found in Section 15.0.

The field supervisor will prepare a daily schedule of field activities and will provide each field team leader with a prepared sample kit. Each kit will be composed of a sample cooler containing sample containers, labels, chain-of-custody forms, blue ice, and a well information file. The well file will include previous and historical water level data, expected casing volume, and any comments generated during preceding water level measurement phases and prior sampling events. Field team leaders will ensure that sample and field kits are complete and that all instruments and sampling equipment are in good working condition.

On arriving at the well site, the following procedures will be implemented:

1. Zero the precalibrated PID to ambient air conditions. With respirators on and from an upwind direction, uncap well and record background and casing headspace readings with a PID as described previously for water level measurements. Respirators may be removed if PID values are at background levels within the breathing zone around the well head. Respirators need not be donned when approaching the well if PID readings and analytical data from the previous two sampling events show no elevated contaminant levels.

2. Record well number, date, pertinent observations (e.g., weather, well condition) station elevation, casing diameter, screened interval, and field instrument identification. Note whether the well has a vent.

3. Record well stickup, depth to water, and total well depth. All measurements will be made from a measuring point marked at the top of casing (TOC). Compare measured values with previous measurements; investigate and document any discrepancies. All measuring devices used to obtain water level and total depth measurements will be decontaminated with deionized (DI) water.

4. Calculate and record casing volume; compare with previous volumes to ensure relative compatibility.

5. Calibrate field instruments against known standards. Record instrument calibration responses, times, and calibration standards used. Field instrumentation is used to monitor the following parameters: pH, temperature, conductivity, alkalinity, and dissolved oxygen (pumped wells only).

6. The decision to pump or bail a well will be made based on the relative efficiency of either method with respect to the amount of purge water to be removed. In general, wells containing less than 4 gallons/casing volume or known to dewater at 1 casing volume will be purged and sampled by bailing. All other wells will be pumped.

7. All wells will be purged and sampled from the top of the water column. Bailers will be slowly lowered into the water column to a depth equal to the length of the bailer being used. Pumps will be placed 2 to 3 feet below the top of the water column and repositioned as necessary in response to water level fluctuations during evacuation. An in-line flow cell consisting of an air-tight chamber fitted for instrument probes will be used on all pumped wells. In addition, the field parameter list described in Item 5 above will include dissolved oxygen measurements for all pumped wells.

8. A portion of the initial water discharged from the well will be collected and the following information recorded: field parameter values (pH, temperature, conductivity, and dissolved oxygen), time, PID reading, pumping rate, and purged volume removed. Similarly, this information will be documented after each casing volume is removed. All purged water will be containerized at the well site.

9. A minimum of five casing volumes will be removed from each well prior to sampling. However, samples will not be collected until field parameters have stabilized from three consecutive casing volumes. Wells which dewater prior to the removal of five casing volumes or stabilization will be exempt from these requirements. Samples will be collected from these wells once sufficient recharge has been attained. Dewatered wells will be given a maximum of 24 hours to recharge. If sufficient recharge has not been attained within a 24-hour period, as many sample fractions as possible will be collected.

10. An alkalinity titration will be performed on a portion of the well water obtained after the fifth or final casing volume has been removed. Titration volumes required to reach colorimetric end points will be recorded along with associated pH values (taken coincidentally).

11. Sample parameters will also be measured and recorded immediately prior to sample collection. Sample labels will be completed to include the following information: well number, time, data, temperature (°C), conductivity, pH, sampler's initials, and dissolved oxygen (for pumped wells only).

12. When pumps are being used, samples will be collected directly from pump discharge lines at low flow rates to avoid agitating samples and possibly degassing of volatiles. If bailed, samples will be collected from bottom decanting bailers.

13. Sample bottles will be rinsed with well water prior to filling. Sample fractions will be filled in the sequence listed in Table 7.1. The VOA and DBCP sample fractions will be filled completely and capped tightly to avoid air bubbles. Except for metals, all remaining sample fractions will be filled to a minimum of 90 percent capacity. Metal fractions will be filtered in the field using 0.45 micron cellulose acetate filters, until each container is filled to a minimum of 70 percent, and preserved with dilute nitric acid to a pH of ≤ 2. Unfiltered nitrate/nitrite fractions will be preserved with sulfuric acid to a pH of ≤ 2. Cyanide fractions will be preserved with dilute NaOH to a pH of 10. All sample fractions will be placed on ice in a cooler immediately upon filling. Sampling technique, sample depth, and fractions collected will be recorded on the sample data sheet, chain-of-custody record, and in the field logbook.

14. The field team leader will sign and date the sample data sheet after ensuring that the sheet has been fully completed and the information has also been recorded in the field logbook. The field team leader will complete the chain-of-custody record before relinquishing the samples.

15. All sampling equipment will be thoroughly decontaminated (deconned) at the well site prior to storage. Except for pumps, all equipment will be cleaned in a solution of COR-approved water and Liquinox cleaner or equivalent, rinsed with COR-approved water and triple-rinsed with deionized water. To decontaminate the inside of the pump, a volume of deionized water equal to three times the volume of the pump and hoses will be pumped through the line. All decontamination water will be containerized at the well site. All cleaned equipment will be wrapped and stored in clean plastic sheeting. The normal means for disposing of well and decontamination water will be to containerize in

Table 7.1: Analyses, Sample Containers, and Preservatives
For Water Samples

Analysis	Sample Containers	Preservatives
Volatile aromatics	(2) 40-ml amber glass	
Volatile organohalogens	(2) 40-ml amber glass	
GC/MS volatiles	(2) 40-ml amber glass	
GC/MS semivolatiles/acid extractables	(2) 1-liter amber glass	
Organosulfur compounds	(2) 1-liter amber glass	
Organochlorine pesticides	(2) 1-liter amber glass	
Nitrogen phosphorus pesticides	(2) 1-liter amber glass	
Hydrocarbons	(2) 1-liter amber glass	
Anions	125-ml plastic (filtered*)	
Nitrate/Nitrite	125-ml plastic (filtered*)	0.5 ml H_2SO_4
Arsenic	500-ml plastic (filtered*)	0.5 ml HNO_3
Mercury	500-ml plastic (filtered*)	0.5 ml HNO_3
ICP metals**	500-ml plastic (filtered*)	0.5 ml HNO_3
Cyanide	1-liter plastic	1 ml NaOH

* The filtering equipment utilizes a Geopump peristaltic pump with a 0.45-micron cellulose acetate filter.

** Analysis by Inductively Coupled Plasma (ICP) emission spectrometry.

a truck-mounted tank. The water will then be transported to an onpost disposal/ treatment facility. If any barrels are used to containerize well and decontamination water, they will be sealed and labeled with an appropriate inventory number, task number, date, job number, contractor(s) name, well number, and content (e.g., ground water).

16. The final activity at the well site will be to remove all sampling equipment and debris from the area.

In addition to the above listed procedures, the following guidelines will be used to mitigate any potential problems that could adversely affect sample integrity:

1. Avoid agitation of VOA samples collected from either pumps or bailers. This will reduce air stripping of volatiles and allow for the collection of more representative samples.

2. Sampling equipment including pumps, hoses, bailers, rope, etc., should contact only the well or a clean plastic surface. Equipment should never contact the ground or any other surface which has the potential to transmit contaminants. This equipment should always be encased or wrapped in clean plastic during transport.

3. Change gloves frequently when handling downhole instruments. Always change gloves after working on compressors or other equipment prior to sampling. New gloves will be worn at the start of well purging and changed immediately prior to sample collection.

4. When working on downhole equipment (bailers, pumps, etc.) either decontaminate tools prior to use or decontaminate the equipment before re-entering the well.

5. Avoid splashing water or dirt on plastic ground cloths. Replace ground cloth if it becomes dirty.

6. Vent gasoline engines downwind at least 30 feet from the well head. Gas tanks should be filled before going to the field. Keep all sampling equipment away from potential gasoline spills or leaks.

7. Replace dropped bottles, lids, or septa with spares from the kit. Avoid contact with edges or inside surfaces of sample bottles.

8. Ensure that septa and Teflon cap liners are in good condition. Check that septa are oriented with Teflon side down. Once full, septa bottles should be transported upside down to inhibit air leakage should any microbubbles form in the water.

9. Avoid sampling when precipitation or windblown dust may contaminate the sample.

10. Do not dip pH indicator paper into samples, check by pouring a small amount of sample over the paper.

11. To avoid unnecessary agitation of the water column, bailers will be lowered slowly into the well. A knot tied in the bailing rope approximately 2 feet above the static water level will serve as a marker below which the bailer will be lowered very slowly.

12. Ensure that a stainless steel protector is emplaced over the well head prior to bailing. This protector will prevent the bailing rope from cutting into the top edge of the PVC casing.

13. When reassembling the filter head assembly, the 0.45 micron filter must be handled with stainless steel tweezers.

14. Sample bottles will be filled from a pump discharge line located upstream of the flow cell.

15. When sharp increases are observed in dissolved oxygen readings, a bailer will be used in place of the pump to sample the well. Pumps will only aerate samples when they are malfunctioning and should be repaired. Pumped samples are generally cleaner and preferable to bailed samples.

8.0 SURFACE-WATER SAMPLING

Surface water sampling procedures will comply with those developed and employed under previous investigations including Task 44 (ESE, 1988) and the Comprehensive Monitoring Program (Stollar, 1988). A summary of these procedures is included herein. Sample fractions, containers, and preservation methods are listed in Table 7.1.

Surface-water samples will be obtained by integrating samples collected over the cross sectional area of the stream. Where the stream is too small to permit this, samples will be collected from the center of the channel just below the stream surface. Water samples from the pond will be collected as grab samples from near the shoreline.

Field parameters (pH, specific conductivity, and temperature) will be measured with field instruments calibrated against known standards. These parameters will be recorded both on a separate data sheet and in a bound field notebook. Other recorded data include date, sample location, sample number, sample fractions, and sampler's name.

Surface-water samples will be collected with a stainless steel dipper, a spare clean sample bottle, or directly with the sample bottle, as appropriate. Samples for organic analysis (VOA, semivolatiles, DBCP, DCPD, and organochlorine, nitrogen phosphorus and organosulfur pesticides) will be collected in amber glass bottles with Teflon-lined caps. Samples for inorganic analysis (anions, total metals-unfiltered, dissolved metals-filtered, cyanide, and nitrate/nitrite) will be collected in polyethylene containers. Dissolved metals fractions will be filtered in the field using 0.45-micron cellulose acetate filters. Both metals fractions will be fixed with dilute nitric acid to a pH of 2. The nitrate fraction will be fixed with sulfuric acid to a pH of 2. The cyanide friction will be fixed with sodium hydroxide to a pH of 10. All sample bottles will be placed on ice and stored at 4°C in a sample cooler immediately upon filling.

9.0 SOIL SAMPLING

The soil sampling program will consist of two general components. The first component will include collection of shallow (0- to 1-foot) samples from each 1-foot-deep boring location. Samples will be collected by driving an 18-inch-long, 2.5-inch-inside-diameter split-barrel sampler equipped with a series of three 6-inch-long stainless steel liners. Blow counts required to drive the sampler a distance of 12 inches will be recorded on the field boring log. The split-barrel sampler will be opened on clean plastic sheeting, and the bottom two steel liners will be removed and retained as an investigative sample. Each stainless-steel-liner containing the investigative sample will be (1) capped with Teflon film and plastic caps, (2) taped, (3) labeled, (4) sealed inside a plastic bag, and (5) placed on ice inside an insulated cooler. Upon completion, each borehole will be backfilled to grade using native surface soil.

The second component of the soil sampling program will include continuous collection of 1-foot samples from ground surface to either the water table or to 5 feet if the water table is not encountered. Samples will be obtained from each 1-foot interval using the hand-sampling procedure described above. Following removal of each sample from the boring, the borehole will be reamed to the top of the next sample interval using a hand auger. The purpose of borehole reaming is to ensure that the sampler can be extracted following the subsequent drive. Each 1-foot sample will be handled according to the procedures described in the preceding paragraph. The investigative samples retained for analysis at each boring location will include the stainless-steel liners comprising the 0- to 1-foot depth interval and the 1-foot interval immediately above the water table. If the water table is not encountered, the liners containing soil from the 4- to 5-foot depth interval will be retained for analysis. Soil from the remaining sample liners will be extracted in the field and placed in approved containers. All soil cuttings will be collected and containerized for storage onpost.

Immediately following completion, all borings drilled to depths greater than 1 foot will be filled with cement-bentonite grout to within 1 foot of the surface. In cultivated areas, borings

will be grouted to a depth of 3-feet below the ground surface. After the grout has set, native surface soil will be used to backfill to grade. During grouting and backfilling, all open holes will be temporarily covered.

All sampling equipment used during both components of the soil investigation will be decontaminated prior to use and between sampling locations. In addition, split-barrel samplers and drive shoes will be decontaminated between sampling intervals. Stainless-steel sample liners will be decontaminated prior to initiating field activities. Decontamination will be performed in accordance with the procedures described in Section 14.2.

The HLA field geologist will document all observations and activities performed at each sampling location in a bound field notebook. Observations will include weather, ground disturbances or soil discoloration, and site conditions. For each sample collected, the field geologist will record boring number, depth of collection, time of collection, and percent recovery. The HLA geologist will also prepare a geologic description of the soil sampled at each location, complete sample labels, and initiate chain-of-custody records.

10.0 SURFACE SOIL SAMPLING

Surface soil samples will be obtained by removing soil at each sampling location to a depth of approximately 2 inches from an area with an approximately 2-foot radius. Sediment will be removed using a clean stainless steel sampling scoop. If frozen ground is encountered, a decontaminated pick or chisel will be used to loosen the soil prior to sample collection. A sufficient amount of sediment to fill all sample containers will be placed in a clean stainless steel bowl. The collected sediment will be homogenized and placed in 8-ounce wide-mouth glass containers with Teflon-lined lids. Five completely filled sample containers will constitute each sample collected at a given location.

All sampling equipment, including sampling scoops, bowls, picks, and chisels will be thoroughly cleaned prior to use and between sampling locations. All equipment will be cleaned in accordance with the decontamination procedures described in Section 14.0. Samples will be collected in laboratory-certified clean sample containers and placed on ice in insulated coolers.

The HLA field geologist will document all observations and activities performed at each sample location in a bound field notebook. Observations will include weather, ground disturbances or soil discoloration, and site conditions. The HLA geologist will also prepare a geologic description of the soil/sediment sampled at each location, complete sample labels, and initiate chain-of-custody records.

11.0 STREAM AND POND SEDIMENT SAMPLING

Sediment samples from streams and ponds will be collected in a manner similar to that for surface soil samples. Sediment will be collected with a stainless steel scoop. The first 1 to 2 inches of the stream or pond bottom will be sampled and placed in 8-ounce wide-mouth sample jars. Site conditions, sediment characteristics, weather conditions, and other pertinent information will be recorded by the sampling team in a bound field notebook. Samples will be stored on ice in insulated coolers.

12.0 BIOTA SAMPLING

At least two types of biota will be sampled, including fish (both whole and fillet samples) and chicken eggs. Other biota will likely be collected for analysis in future sampling programs. The sampling procedures for any additional biota types will be contained in applicable work or sampling plans.

12.1 FISH

Fish samples may be collected through the use of an electrical shocker. For this procedure, the electroshocking device is lowered into the water and an electric current is passed between two electrodes. The shock generated stuns nearby fish, which are then collected. Fish specimens are collected using decontaminated steel tongs or clean cotton gloves, and handling is kept to a minimum. If electroshocking is not done, another procedure such as collection with a net may be followed. After collection, specimens will be immediately wrapped in hexane-rinsed and double DI water rinsed aluminum foil. The foil wrapped specimen will be placed in a ziplock bag and a sample label will be placed on the outside of the bag. The sample will be placed on ice in an insulated cooler for transportation and storage. Custody and shipment procedures as discussed in Section 13.0 will be followed.

12.2 DOMESTIC EGGS

Samples of domestic chicken eggs may be collected from one or more locations offpost. Eggs from several chickens will be collected at one time so that a broader cross section of the population is achieved and to ensure that an adequate mass of sample for analysis is collected. Approximately 6 to 12 eggs will be collected and combined to make one sample.

Specimens will be collected using either properly decontaminated steel tongs or hexane-rinsed aluminum foil. Each egg will be wrapped separately in hexane-rinsed aluminum foil and then placed in a cardboard egg carton. When all eggs for a sample have been collected, a sample label will be placed on the carton and the sample will be placed on ice in an insulated cooler.

Several layers of bubble-wrap material will be placed inside the cooler to inhibit breakage of the eggs. Custody and shipment procedures as discussed in Section 13.0 will be followed.

13.0 SAMPLE CUSTODY AND TRACKING

To maintain and document sample possession, chain-of-custody procedures are required. These procedures are necessary to ensure the integrity of samples from collection to data reporting. Chain-of-custody records provide the ability to trace possession and handling of samples from the time of collection through analysis and data reporting.

A sample is considered under custody if:

- It is in your possession; or
- It is in a designated secure area.

Personnel collecting samples are responsible for the care and integrity of samples until samples are properly transferred or dispatched. Therefore, the number of people handling a sample should be kept to a minimum.

13.1 FIELD SAMPLE CUSTODY

A chain-of-custody form (example contained in the QA Plan) will be completed by the sampler. For water samples, chain-of-custody forms will be developed for each matrix sample. For any soil or solid samples collected, several samples may be included on the same custody form. The sampler will sign the form where indicated and will record site type, site identification, sample date, time, depth, and sampling technique for each sample collected. Each Chain-of-Custody Form will be completed to the extent possible prior to sampling. The sampler will check off each sample analysis required on the Chain-of-Custody Form and will check the sample tag and chain-of-custody record for accuracy and completeness. The field QA/QC Coordinator, as defined in the QA Plan, or a designated field representative, will determine whether improper custody procedures merit resampling. Only when the chain of custody has been verified may the sampler relinquish custody of the samples.

13.2 TRANSFER OF CUSTODY

When transferring custody of samples, the individuals relinquishing custody and receiving custody will sign, date, and record the time on the Chain-of-Custody Form. The Chain-of-Custody Form documents the transfer of samples from the sampler to the analytical laboratory. To transfer a sample from the contamination area to the support zone, the sampler will relinquish custody of samples to the Sample Coordinator for packaging and shipment. This transfer will occur in the Contamination Reduction Zone (CRZ) in the vicinity of the decontamination and support trailer or at the site of the investigation. The Sample Coordinator will check the information on the sample tags and Chain-of-Custody Form for completeness and consistency. The sample number, date, sampler, and the sample identification number will be entered into the Sample Control Log.

13.3 SAMPLE SHIPMENT

The following discussion outlines generic procedures for shipment of analytical samples. Procedures for different media sampled vary only slightly.

1. The Sample Coordinator will place the sample in a plastic ice chest with appropriate preservation material tightly packed with suitable packing material. The original Chain-of-Custody Form will be signed and dated, and the time recorded will be by the Sample Coordinator prior to transferring custody for shipment. A notation will be made in the remarks section of the record indicating method of shipment, courier's name, and other pertinent information. The Chain-of-Custody From will be sealed in an envelope, and a tamper-proof seal will be placed on the envelope flap. The envelope will be taped to the inside of the ice chest with the name and address of the receiving laboratory prominently displayed.

2. The Sample Coordinator will close and seal the ice chest with a tamper-proof tag, such as evidence tape. The Sample Coordinator will fill out the ice chest tag as described above with the exception that the sample number will not be necessary (several samples may be placed in each ice chest). The seal will be attached to the ice chest in such a way that it is necessary to break it to open the ice chest. All tags must be applied to sample containers and ice chests by the Sample Coordinator. The ice chest will be taped closed by wrapping each end at least twice with either fiberglass reinforced tape or a strong adhesive tape. Paper tape or "Scotch" tape will not be allowed. The ice chest will be taken directly to the shipping agent by the Sample Coordinator, and custody will be relinquished to the analytical laboratory through the shipping agent.

3. For solid and liquid samples, the Sample Coordinator will affix a Hazardous Substance Notification Label prominently on the ice chest. The Sample Coordinator will indicate that the hazardous substance in the container is either a solid or liquid by crossing out the inappropriate term with a black felt tip pen. The ice chest is to be weighed, and a

completed Restricted Articles Shipment Form (airbill) will be attached to an ice chest to be shipped. The Sample Coordinator will retain the shipper's copy of the airbill and will file a copy of the airbill in each appropriate field file. The packed weight of each ice chest must not exceed 150 pounds. Sample copies of Hazardous Substance Notification Labels and airbills are included in the QA Plan. Additional information regarding shipment of hazardous materials may be obtained from the Federal Express Restricted Articles Information Extension (telephone number (800) 238-5355), or from Airborne Express at (303) 288-0075.

4. Chain-of-Custody Forms will be completed in triplicate. Shipped samples must be accompanied by the original chain-of-custody record. One copy will be placed in the field file and the other copy will be sent to the Field QA/QC Coordinator.

13.4 SAMPLE TRACKING

Prior to all sampling events, the field supervisor will discuss with the QA/QC Coordinator or Project Manager the following items:

- Review of sampling protocol (e.g., fractions to be collected and preservation techniques)
- Locations to be sampled
- Sample identification numbers to be used
- Type, location, and quantity of QA/QC
- Turnaround time to be requested
- Analytical laboratory

At this time, sample numbers and tag numbers for individual containers will be assigned. Sample labels will be printed with the site ID, tag number, container type, analytical method, and preservation technique for each fraction to be collected. Chain-of-custody forms will be printed with all of the above information. Labels and chain-of-custody forms will be completed with time, date, sampling personnel, and sampling medium and technique when the sample is actually collected.

After each sampling event is completed, the field supervisor will contact the QA/QC Coordinator or Project Manager within two days to confirm the following:

- Review of samples collected
- Number of containers shipped
- Airbill number

- Time and location of sample shipment and expected arrival time at the analytical laboratory

After samples have been received by the analytical laboratory, they will be initiated into the data tracking system. This system is described in the Data Management Plan (DMP) (HLA, 1989c).

14.0 DECONTAMINATION

All equipment that comes in contact with potentially contaminated soil or water, including equipment used for drilling, geophysical logging, soil and water sampling, water-level measuring and sample preparation, will be cleaned prior to and after each use on this project. All water used will be COR-approved or deionized water. Decontamination will consist of combinations of steam cleaning and/or detergent (Liquinox or equivalent) wash, water rinse, and deionized water rinse.

14.1 DECONTAMINATION PAD

The existing decontamination pad located in Section 36 at RMA will be used for decontamination of large sampling equipment. The pad includes a steam cleaner and a sump for the collection of decontamination wastewater. Decontamination water is routinely removed from the sump and disposed according to PMRMA-approved procedures for the site.

14.2 DRILLING, MONITORING, AND WELL-INSTALLATION EQUIPMENT

All equipment used for drilling, soil sampling, and well installation will be thoroughly decontaminated prior to initiating drilling operations. This initial decontamination will consist of steam cleaning with COR-approved water and will be performed at the Section 36 decon pad. In addition, all well installation materials, including surface casings, well casings and screens, protector casings, and fittings, will also be decontaminated prior to use. These materials will be steam cleaned at the Section 36 decontamination pad, allowed to air dry, wrapped in plastic, and stored in a designated onpost area. Clean polybutyrate tubes for soil sampling will be provided by the manufacturer and will not require further decontamination prior to use.

During drilling operations, all downhole equipment will be thoroughly decontaminated in the field upon completion of each boring or well. Field decontamination will be accomplished using a trailer-mounted portable steam cleaner and a clean water tank filled with COR-approved water. Field decontamination will be performed in a manner such that all rinse water is

containerized. Rinse water will be pumped into truck-mounted storage tanks and transported to the Section 36 decon pad for disposal.

All well installation materials will remain wrapped in plastic until immediately prior to use. Care will be taken to ensure that materials do not contact the ground surface or potentially contaminated equipment. Prior to placement, all materials will be visually inspected for signs of contamination and, if necessary, steam cleaned in the field using the field decontamination procedures described above. Clean gloves will be worn when handling all unwrapped well installation material.

Upon completion of the drilling program, all equipment will be steam cleaned at the Section 36 decontamination pad prior to removal from the site.

14.3 GEOPHYSICAL LOGGING EQUIPMENT

If geophysical logging is required, the geophysical cable and tools will be decontaminated prior to and after logging operations between monitoring wells and borings. The cable will be cleaned by washing with a disposable soap-impregnated cloth, rinsing with fresh water, and rinsing again with distilled water. The logging equipment must be decontaminated after removal from each well or borehole to avoid cross-contamination between wells or boreholes.

14.4 WELL-DEVELOPMENT AND AQUIFER TESTING EQUIPMENT

All equipment used for well development will be decontaminated prior to and after use at each well. This will include decontamination of all pumps, purging bailers, and downhole piping. The procedures for decontaminating this equipment are described in Section 14.6.

14.5 WATER-LEVEL MEASUREMENT EQUIPMENT

The electrical (sounding) tape or steel tape used to measure water levels will be cleaned to avoid chemical cross-contamination between wells. Decontamination will consist of rinsing the tape with deionized water as it is being removed from the well.

14.6 GROUND-WATER SAMPLING EQUIPMENT

All ground-water sampling equipment will be decontaminated between sampling locations. Bailers and filtering equipment will be decontaminated by washing in a detergent solution (Liquinox or equivalent), rinsing with COR-approved water, rinsing with deionized water, allowing to air dry, and wrapping in plastic. Pumps and discharge tubing will be decontaminated by pumping an amount of deionized water equivalent to three times the total volume contained within the pump and tubing through the system. Probes used to measure field parameters will be cleaned by rinsing with deionized water. When bailing, a new nylon rope will be used at each well.

14.7 SEDIMENT AND SURFACE-WATER SAMPLING EQUIPMENT

Equipment used for collection of sediment and surface-water samples will be decontaminated between sampling locations. Decontamination procedures will include the following:

1. Washing in detergent solution (Liquinox or equivalent)
2. Rinsing with COR-approved water
3. Rinsing with deionized water followed by air drying
4. Wrapping equipment in clean plastic

14.8 PERSONNEL

HLA will provide all protective clothing for its own personnel and subcontractors and the equipment necessary to comply with decontamination procedures specified in the HSP.

The following personnel decontamination procedures will be followed:

1. Remove disposable booties (if used) and place into plastic bag for disposal.
2. Wash neoprene boots with detergent solution and rinse with clean water.
3. If gross contamination is present, wash outer gloves in detergent solution and rinse in clean water. Remove outer gloves and place into plastic bag for disposal.
4. Take off air-purifying respirator (if used) or belt of self-contained breathing apparatus straps (if used) and remove coveralls. Starting at the neck, roll the coveralls off from the inside out and down past the boots. Take care to prevent the release and dispersion of dusts that may have accumulated on the coveralls, and do not contaminate clothing

inside the coveralls during removal. Place coveralls into the disposable plastic bag. Remove boots, decontaminate, and retain for subsequent reuse.

5. Remove the respirator and place the spent filters into the plastic bag designated for disposal. Clean and disinfect the respirators and place into a plastic bag for storage.

6. Remove latex liner gloves.

7. Thoroughly wash hands and face.

8. Place all disposable protective equipment in disposable bags. These bags will then be placed into 55-gallon barrels for disposal.

15.0 FIELD DOCUMENTATION

All field personnel will be required to maintain a written record of their daily activities. All records will be kept on prepared forms that will be signed and dated by field personnel at the end of the day. Additionally, this information will be recorded in a bound field notebook, which will also be signed and dated each day. Field books will be numbered and checked out daily to individual personnel or field team leaders, as appropriate. Field book custody will be recorded on the form shown in Figure 15.1. Field books will be kept in a secured area at the support facility when not in use. All field documentation will be submitted to PMRMA upon completion of the field program.

15.1 WATER-RELATED ACTIVITIES

Field documentation forms will be provided for each water-related activity. Examples of the forms to be used for water-level measurement and ground-water/surface-water sampling are presented in Figures 15.2 and 15.3, respectively. Example sample labels and chain-of-custody forms for water samples are provided in the QA Plan.

15.2 BOREHOLE-RELATED ACTIVITIES

The drill site geologist will maintain a record of activities at the drill site on the form shown in Figure 15.4. The information recorded on this form will provide a time record of all drill site activities and personnel. Boring abandonment information will also be recorded on this form. The geologist will also prepare a lithologic description of each boring on a Field Log of Boring form (Figure 15.5). Sample labels and chain-of-custody forms for any samples collected during boring activities are illustrated in the QA Plan.

15.3 WELL-RELATED ACTIVITIES

For borings completed as wells or piezometers, all completion information will be recorded on a Field Well Completion Form (Figure 15.6). Well development information will be included on this form as well.

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FIELD NOTEBOOK CHECK OUT / CHECK IN

PROJECT ____________________ PROJECT NUMBER ____________________

LOCATION ____________________ SUPERVISOR ____________________

NOTEBOOK NUMBER	CHECK OUT			CHECK IN		
	DATE	TIME	INITIAL	DATE	TIME	INITIAL

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U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Commerce City, Colorado

Figure 15.1

FIELD NOTEBOOK CUSTODY FORM

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RECORD OF ACTIVITIES AT WELL SITES
WATER LEVEL MEASUREMENTS

PROJECT ______________________ PROJECT NUMBER ______________________

LOCATION ______________________ SUPERVISOR ______________________

Well No.	Casing Dia. (in.)	Date	Time	PID Reading		Stick Up		Water Level		Total Depth (Feet)	Measuring Device	Sampler Initials	Comments
				Bkgnd	TOC	(Feet)	(Tenths)	(Feet)	(Tenths)				

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Commerce City, Colorado

Figure 15.2

WATER-LEVEL MEASUREMENT FORM

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GROUND-WATER SAMPLING FORM

Job Name ______
Job Number ______
Recorded by ______ (Signature)

Well No. ______
Well Type: ☐ Monitor ☐ Extraction ☐ Other ______
Well Material: ☐ PVC ☐ St. Steel ☐ Other ______
Date ______ Time ______
Sampled by ______ (Initials)

WELL PURGING

PURGE VOLUME

Casing Diameter (D in inches):
☐ 2-inch ☐ 4-inch ☐ 6-inch ☐ Other ______
Total Depth of Casing (TD in feet BTOC): ______
Water Level Depth (WL in feet BTOC): ______
Number of Well Volumes to be purged (# Vols)
☐ 3 ☐ 4 ☐ 5 ☐ 10 ☐ Other ______

PURGE METHOD

☐ Bailer - Type: ______
☐ Submersible ☐ Centrifugal ☐ Bladder; Pump No.: ______
☐ Other - Type: ______

PUMP INTAKE SETTING

☐ Near Bottom ☐ Near Top ☐ Other ______
Depth in feet (BTOC): ______ Screen Interval in feet (BTOC): from ______ to ______

PURGE VOLUME CALCULATION

$$\left(\underset{\text{TD (feet)}}{\_\_\_\_} - \underset{\text{WL (feet)}}{\_\_\_\_} \right) \times \underset{\text{D (inches)}}{\_\_\_\_}^{2} \times \underset{\text{\# Vols}}{\_\_\_\_} \times 0.0408 = \underset{\text{Calculated Purge Volume}}{\_\_\_\_} \text{ gallons}$$

PURGE TIME

______ Start ______ Stop ______ Elapsed

PURGE RATE

Initial ______ gpm Final ______ gpm

ACTUAL PURGE VOLUME

______ gallons

FIELD PARAMETER MEASUREMENT

Minutes Since Pumping Began	pH	Cond. (μmhos/cm)	T ☐ °C ☐ °F	Other ______

Minutes Since Pumping Began	pH	Cond. (μmhos/cm)	T ☐ °C ☐ °F	Other ______
Meter Nos.				

Observations During Purging (Well Condition, Turbidity, Color, Odor): ______
Discharge Water Disposal: ☐ Sanitary Sewer ☐ Storm Sewer ☐ Other ______

WELL SAMPLING

SAMPLING METHOD

☐ Bailer - Type: ______
☐ Submersible ☐ Centrifugal ☐ Bladder; Pump No.: ______
☐ Same As Above
☐ Grab - Type: ______
☐ Other - Type: ______

SAMPLE DISTRIBUTION Sample Series: ______

Sample No.	Volume/Cont.	Analysis Requested	Preservatives	Lab	Comments

QUALITY CONTROL SAMPLES

Duplicate Samples

Original Sample No.	Duplicate Sample No.

Blank Samples

Type	Sample No.

Other Samples

Type	Sample No.

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U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Commerce City, Colorado

Figure 15.3

GROUND-WATER / SURFACE-WATER SAMPLING FORM

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PAGE ____ OF ______

RECORD OF ACTIVITIES AT DRILL SITE

WELL OR BORING NUMBER ____________________

DATE ______________________

LOCATION ____________________

PROJECT NUMBER ______________

HYDROGEOLOGIST ____________________

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Commerce City, Colorado

Figure 15.4
RECORD OF ACTIVITIES
AT DRILL SITE

FIELD LOG OF BORING SHEET ____ OF ____

LOCATION OF BORING:	PROJECT:	BORING NO.
		TOTAL DEPTH:
	JOB NO.:	LOGGED BY:
	PROJ. MGR.:	EDITED BY:
	DRILLING CONTRACTOR:	
	DRILL RIG TYPE:	
	DRILLERS NAME:	
	SAMPLING METHODS:	
	HAMMER WT.:	DROP:
	STARTED, TIME:	DATE:
	COMPLETED, TIME:	DATE:

BORING DEPTH (ft.)			
CASING DEPTH (ft.)			
WATER DEPTH (ft.)			
TIME:			
DATE:			

BACKFILLED, TIME: DATE: BY:

SURFACE ELEV.: DATUM:

CONDITIONS:

SAMPLE DEPTH	SAMPLER TYPE	BLOWS/6-IN.	INCHES DRIVEN	INCHES RECOVERED	SAMPLE CONDITION	DRILLING RATE (min/ft)				DEPTH IN FEET	GRAPHIC LOG	
										1		
										2		
										3		
										4		
										5		
										6		
										7		
										8		
										9		
										10		

FF7 HARDING-LAWSON ASSOCIATES

Prepared for:
U.S. Army Program Manager's Office
For Rocky Mountain Arsenal
Commerce City, Colorado

Figure 15.5

FIELD LOG OF BORING

FIELD WELL COMPLETION FORM

JOB NAME:

JOB NUMBER: | PROJECT MANAGER:

LOGGED BY: | EDITED BY:

WELL NAME: | DATE:

DRILLING COMPANY:

EQUIPMENT: ☐ ______ INCH HOLLOW STEM AUGER | DRILLER:

☐ ______ INCH ROTARY WASH | HOURS DRILLED:

GALLONS OF WATER USED DURING DRILLING: GALLONS

METHOD OF DECONTAMINATION PRIOR TO DRILLING:

DEVELOPMENT

METHOD OF DEVELOPMENT:

DEVELOPMENT BEGAN DATE: TIME:

YIELD:	TIME:	DATE:
GPM	FROM TO	
GPM	FROM TO	
GPM	FROM TO	
GPM	FROM TO	

TOTAL WATER REMOVED DURING DEVELOPMENT: GALLONS

DESCRIPTION OF TURBIDITY AT END OF DEVELOPMENT: ☐ CLEAR ☐ SLIGHTLY CLOUDY ☐ MOD. TURBID ☐ VERY MUDDY

ODOR OF WATER:

WATER DISCHARGED TO: ☐ GROUND SURFACE ☐ TANK TRUCK ☐ STORM SEWERS ☐ STORAGE TANK ☐ DRUMS ☐ OTHER ______

DEPTH TO WATER AFTER DEVELOPMENT: FEET

MATERIALS USED

______ SACKS OF ______ SAND

______ SACKS OF ______ CEMENT

______ GALLONS OF GROUT USED

______ SACKS OF POWDERED BENTONITE

______ POUNDS OF BENTONITE PELLETS

______ FEET OF ______ INCH PVC BLANK CASING

______ FEET OF ______ INCH PVC SLOTTED SCREEN

______ FEET OF ______ INCH STEEL CONDUCTOR CASING

______ YARD^3 CEMENT-SAND (REDI-MIX) ORDERED

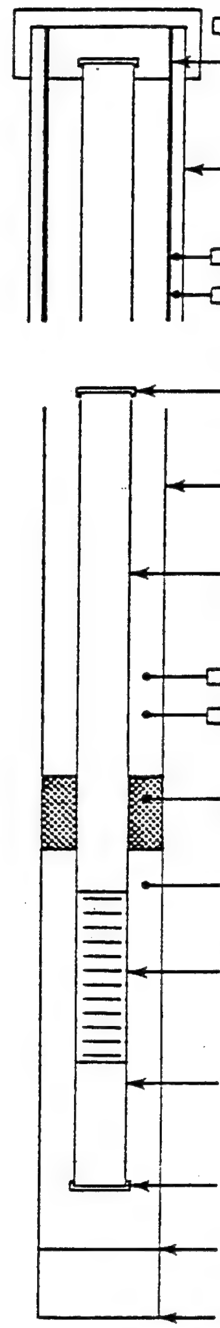
______ YARD^3 CEMENT-SAND (REDI-MIX) USED

CONCRETE PUMPER USED? ☐ NO ☐ YES

NAME ______

WELL COVER USED: ☐ LOCKING STEEL COVER ☐ CHRISTY BOX ☐ OTHER ______

SILT TRAP USED? ☐ NO ☐ YES



NOT TO SCALE

ADDITIONAL INFORMATION: ______

Prepared for:
U.S. Army Program Manager's Office For Rocky Mountain Arsenal
Commerce City, Colorado

Figure 15.6
FIELD WELL COMPLETION FORM

16.0 WASTE DISPOSAL AND TREATMENT

This section describes waste handling procedures and the inventory tracking system necessary to handle volumes of liquid or solid wastes generated during RIFS1 field investigations. The objective of this waste handling program is to standardize procedures for waste characterization, inventory, storage, management, and disposal of all potentially hazardous wastes generated during the investigative activities.

Although field investigations at RMA generate a large volume of potentially contaminated soil and water, contaminants are not detectable in all of this material. To avoid unnecessary handling, storage, and disposal of nonhazardous waste materials, contractors at RMA have established a waste handling program in conjunction with PMRMA and EPA (EPA, 1985).

16.1 CONTAINERIZATION

Wastes generated during the field investigations will include soil, water, and clothing. Waste solids and clothing will be containerized in drums. Depending on circumstances of collection, water will be placed in drums or holding tanks.

Two types of drums, both approved by the U.S. Department of Transportation (DOT), are used by PMRMA contractors for storage of potentially contaminated materials. Solids are stored in reconditioned steel hazardous waste drums, which have removable lids sealed with a metal ring. Liquids are stored in reconditioned drums approved by DOT for potentially contaminated waste, which have welded lids with small access ports and plugs. Individual drums are used for one type of material only (liquid, soil, or clothing). Drums, especially those containing liquids, will not be overfilled. Precautions will be taken to prevent the drums from freezing. For materials that are a mixture of soil and water (as in saturated drill cuttings from well installations), the drum will be marked as a liquid and will be stored in a warehouse designed for liquid drum storage.

At the completion of each day's field activities or when a drum is filled, the field geologist will close and seal the drum and label it on two sides and the lid with the job number, contents,

boring or well number, Julian date, and the individual's initials. A permanent white or yellow paint marker will be used to label the drums. Drums will be transported to an approved storage warehouse designated by PMRMA.

16.2 INVENTORY

To maintain an accurate inventory of wastes generated during geotechnical activities, a waste material tracking system will be utilized. This system of waste inventory was developed under previous programs at RMA and is currently in use. Mechanisms for tracking drummed and laboratory wastes and wastewaters generated by well development, purging, and sampling are described below.

16.2.1 Drummed Waste

Prior to initiation of field investigations an estimate of the total amount of solid and liquid wastes to be generated will be developed. Estimates will include the number of borings, excavations, well sampling, hydrologic well testing, and related activities that may be necessary. The current inventory and projection of future waste quantities will be used to assess the quantity and types of storage necessary for drummed wastes.

Estimated waste quantities will be used to estimate the number of drums needed for geotechnical activities. This quantity of empty, unmarked barrels will be kept onsite in a clean area. When a drum is needed by a field crew, the waste handling coordinator will assign a drum identification number, which will be recorded in a permanent drum inventory logbook along with the site number, Julian date, and job number. The identification number will be painted on the side and lid of the drum before it is removed from the clean storage area.

When the drum is sealed and labeled by the site geologist, the waste handling coordinator will be notified via radio of the contents and date sealed, and this information will be entered into the drum inventory logbook. When the field crew removes the drum and transports it to the appropriate storage facility, the waste handling coordinator will be notified via radio as to the date, storage building number, and condition of the drum. If the condition of the drum is

questionable or if any of the labeled information does not agree with the information listed in the drum inventory logbook, the drum will not be placed inside the storage warehouse. The drum will remain in a designated location immediately adjacent to the storage warehouse, and the waste handling coordinator will investigate and correct any errors.

16.2.2 Decontamination, Well Development, and Sampling Evacuation Water

Procedures for handling water generated during decontamination, well development, or well evacuation in conjunction with water-quality monitoring will be consistent with the procedures currently followed at RMA (EPA, 1985). These procedures will reduce inefficient use of labor caused by lack of coordination of decontamination and wastewater disposal needs and schedules as well as lack of bulk storage tank capacities. HLA will coordinate equipment decontamination and the handling and storage of waste water for RIFS1.

16.2.3 Soil Sample Library

Soil samples collected during the geotechnical program will be inventoried, and inventory data will be entered into the RIFS1 data base. Access to the soil cores will be coordinated in a manner similar to that used for the confidential library system described in the DMP.

16.2.4 Wastes From Pilot Testing

Wastes generated during pilot testing may include spent carbon, which will be handled and disposed or regenerated by the vendor supplying the carbon contactors. The vendor will transport the spent carbon back to central facilities for thermal regeneration or will landfill the spent carbon as a hazardous waste. Liquids generated during pilot testing will be drummed or disposed to the South Adams County Sanitary Sewer System.

Any other solid wastes generated during pilot testing will be containerized, inventoried, and stored onpost using procedures consistent with those for drilling wastes.

16.3 TRANSPORTATION

Containerized wastes generated by the geotechnical program activities will be removed from offpost sites and will be transported to a designated storage warehouse at RMA.

16.4 STORAGE

Wastes generated during the field activities will be containerized and transported to a storage facility as previously described. Wastes may be stored at this location until interim onsite disposal or treatment facilities are available or until a final site remedy has been identified.

16.4.1 Storage Facility Requirements

Storage facilities currently used by RMA program contractors will be used by HLA for the duration of field activities. Storage facilities will be consistent with ARARs, including any substantive pertinent aspects of RCRA for storage of solid and liquid wastes. The storage facilities are currently managed by Weston, and in general, the requirements which are met are as follows:

- Incompatible wastes are separated by dikes, berms, walls, or other devices, and the storage areas are enclosed with fencing
- Ignitable or reactive wastes are stored 50 feet from the property line and are separated from any ignition source
- Adequate aisle space is allowed between rows of drums and tanks
- Hazardous waste containers are maintained in good condition
- Containers are made of or lined with materials that will not react with the hazardous waste being stored
- The containers remain closed at all times during storage and may not be opened, handled, or stored in a manner that could cause rupture or leakage
- Weekly visual inspection of the containers and their containment are undertaken to detect any leaking containers or any deterioration of the containers and containment system
- The containers are elevated to prevent contact with any accumulated liquid within the containment system
- The containment system is designed to be free of cracks, impervious to the waste being stored, and sloped

- A notice of contents and floor plan is posted at doors leading into each of the storage areas

The necessary requirements for storage of liquid wastes include those for solid waste storage plus the following additional requirements:

- A containment berm must be provided to hold 10 percent of the total volume of the containers or the volume of the largest container, whichever is larger
- All floor drains within spill control berms must be capped or plugged
- Eyewash stations and emergency showers must be provided within each storage area
- The walls, floors, and roofs of all storage facilities will be maintained in good physical condition

To meet the above requirements, prior to storage of liquids and unknowns in storage warehouses provided by PMRMA, a Hypalon liner will be spread on the floor and surrounded with a 6-inch berm to contain any possible spills. In the event that the integrity of the Hypalon liner cannot be maintained under normal traffic conditions, an equivalent liner will be used. In addition, all floor cracks and drains will be plugged and patched to prevent spills from escaping the buildings. All warehouses will be equipped with fire extinguishers, emergency eyewashes, emergency showers, air venting systems, and signs alerting personnel that they are entering a restricted area.

16.4.2 Procedures for Storage (Warehouse) Activities

Drums are currently transported to the designated warehouse staging area, where they are placed on oak pallets, four to a pallet. The drums are removed from the trucks using a teleporter forklift fitted with a barrel-holding attachment. After the drums are loaded onto a pallet, a forklift is used to move them within the storage warehouse. Drums containing solid wastes are stacked three pallets high, and drums containing liquids are stacked two pallets high. Because the liquid storage warehouse floor is covered with a Hypalon liner, the present procedure of four drums on an oak pallet transported by a rubber-tired forklift minimizes the amount of travel over the Hypalon liner.

16.5 TREATMENT AND DISPOSAL

At this time, water generated by well purging and decontamination procedures is treated onsite. It is not anticipated that soil treatment will be performed onsite within the duration of the geotechnical program.

16.5.1 Solids

Contaminated solid wastes may be sampled and analyzed in the future. The results will determine treatment needs and eventual disposal. Disposition of solid waste will be determined on a case-by-case basis.

16.5.2 Water

All purged water generated during field activities will be containerized and stored as previously described or discharged to the South Adams County Sanitary Sewer System.

16.5.3 Drummed Waste

Drummed wastes will be stored at RMA in accordance with state and federal EPA regulations. Final disposal will be at the direction of PMRMA.

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18.0 ACRONYMS AND ABBREVIATIONS

ASTM	American Society for Testing and Materials
COE	U.S. Army Corps of Engineers
COR	contracting officers representative
CRZ	Contamination Reduction Zone
DBCP	Dibromochloropropane
DC	direct current
DCPD	Dicyclopentadiene
DI	deionized
DMP	Data Management Plan
DOT	U.S. Department of Transportation
EPA	U.S. Environmental Protection Agency
ESE	Environmental Science and Engineering
FOP	Field Operations Procedures Plan
GC/MS	gas chromatography/mass spectrometry
HLA	Harding Lawson Associates
HSP	Health and Safety Plan
ICP	Inductively Coupled Plasma
ID	inside diameter
OD	outside diameter
OVA	organic vapor analyzer
PID	photoionization detector
PMRMA	office of the Program Manager for Rocky Mountain Arsenal
QA	Quality Assurance
QC	Quality Control
RMA	Rocky Mountain Arsenal
SP	self potential

TOC	top of casing
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
UTM	Universal Transverse Mercator
VES	vertical electric sounding
VOA	volatile organic analyses
VOCs	volatile organic compounds
WESTON	Roy F. Weston Inc.